State of California
THE RESOURCES AGENCY
Department of Water Resources
Northern District

UPPER EEL RIVER DEVELOPMENT
INTERIM REPORT

WATER QUALITY

Office Report

AUGUST 1966

FOREWORD

In July 1964, the Department initiated an Advance Planning Program of the Upper Eel River Development. The initial objective in this program is to select the most favorable conveyance route for delivering project water from the Middle Fork Eel River to the Sacramento Valley.

Two alternative conveyance routes are under consideration. (1) by pumped diversion from the Middle Fork Eel to English Ridge Reservoir on the main Eel with subsequent gravity diversion to Clear Lake and thence via either Putah or Cache Creeks to the Sacramento River; or (2) by gravity diversion to elements of the Glenn Reservoir Complex on Thomes and Stony Creeks with subsequent release to the Sacramento River.

The route selection studies, which are scheduled for completion in June 1967, will be published in Bulletin No. 171-1, "Upper Eel River Development, Interim Report".

This report summarizes the water quality studies which were made for route selection. On the basis of this study, it is concluded that there is not sufficient differences in the water quality aspects of the two routes to indicate a routing preference.

The study did point out a number of potential water quality problems on each route. They will be thoroughly evaluated for the selected route in the next phase of the Advance Planning Program.

TABLE OF CONTENTS

Page

FIGURES

TABLES

APPENDIX

PLATES
(Plates are bound at end of report)

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

EDMUND G. BROWN, Governor
HUGO FISHER, Administrator, The Resources Agency
WILLIAM E. WARNE, Director, Department of Water Resources
ALFRED R. GOLZE', Chief Engineer
JOHN R. TEERINK, Assistant Chief Engineer

NORTHERN DISTRICT

Gordon W. Dukleth . . . . District Director

Robert E. Foley . . . . . Chief, Special Investigations Section

This report was prepared
under the supervision of

Robert F. Clawson . . . . Senior Engineer, Water Resources

by

Richard L. Rosenberger. . Water Resources Engineering Associate

assisted by

Jerry E. Dillard . . . . Engineering Aid II

CALIFORNIA WATER COMMISSION

RALPH M. BRODY, Chairman, Fresno

WILLIAM H. JENNINGS, Vice Chairman, La Mesa

JOHN W. BRYANT, Riverside

JOHN P. BUNKER, Gustine

IRA J. CHRISMAN, Visalia

JOHN J. KING, Petaluma

EDWIN KOSTER, Grass Valley

NORRIS POULSON, La Jolla

MARION R. WALKER, Ventura

-----0-----

WILLIAM M. CARAH
Executive Secretary

ORVILLE L. ABBOTT
Engineer

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In this report water quality information and data assembled during this study, are evaluated to determine essential differences or problems which would make one proposed route more favorable than the other as far as water quality is concerned. During the course of the study, physical, chemical, and biological factors related to water quality were determined for the potential project water and the waters which will be affected along each of the proposed conveyance routes. Estimates of water quality changes which may occur due to the transbasin conveyance of project water are presented in the report. Trial salt routings were made from the Middle Fork Eel River to the Sacramento River for each of the proposed conveyance routes.

As a result of this water quality evaluation for route selection, it does not appear that there is enough difference between the Clear Lake route and the Glenn route to give one priority over the other. In other words, there are no economically significant water quality factors which were found to weigh in favor of one route over the other.

One outstanding difference exists, however, between the two routes which should not be ignored. This difference rests in the fact that if the Clear Lake route is chosen, the export water will be passing through an established water oriented recreational area, whereas a Glenn complex recreational area is not established. Aesthetics, therefore, and its influence on recreation are much more important in considering the Clear Lake route than in considering the Glenn route.

In view of this, as much flexibility as possible should be designed into the export features of the Clear Lake route in order to control water quality. It will be shown in this report, for instance, that at times the turbidity level in the import water may be higher than the turbidity level present in the Upper Arm of Clear Lake. While it is not expected that increased turbidity for short periods of time in the Upper Arm of Clear Lake would be a detriment to the use of the lake, the potential for adverse public reaction because of turbid Eel River inflow is very real.

Taking into consideration possible aesthetic problems involved in the Clear Lake route it is recommended that:

1. Multiple level outlets be installed on the entrance to Garrett Tunnel for turbidity control.

2. The Cache Creek route be given preference over the Putah Creek route if other considerations are equal.

3. Consideration be given to the possibility of diverting all of the export water through Clear Lake during the period from the first of June to the end of November.

The primary water quality benefit derived from routing Eel River water through Clear Lake would be an improvement in the lake's mineral quality. Clear Lake's existing water quality problems such as algae growth, would not be solved by the addition of Eel River water. Also, it is not expected that import water would lower the lake's temperature to the point that the existing warm water fishery within the lake would be modified.

Conclusions regarding some of the water quality effects of diverting Middle Fork Eel River water (or Upper Eel River water) into the proposed conveyance channels are summarized below:

1. The mineral quality of the conveyance channels (either route) would be improved by Eel River water.

2. The Upper Arm of Clear Lake may be more turbid than it normally is during the early part of summer.

3. The overall productivity of Clear Lake would not be substantially modified due to the importation of Eel River water - there would still be an algae problem.

4. The temperature of Clear Lake would be lowered a maximum of about 8°F in August, utilizing current project operation schedules.

5. Regardless of the conveyance route chosen from Clear Lake to the Sacramento River, the mineral quality of the export water would be satisfactory for nearly all beneficial uses.

6. In the routing via Putah Creek and Lake Berryessa the productivity of the uppermost reaches of Lake Berryessa would in all probability be increased; however, it is not anticipated that there would be a widespread or significant increase in the growth of aquatic organisms due to the introduction of export water.

7. It appears that the depth and volume of Lake Berryessa is sufficient to maintain the temperature of the export water released at Monticello Dam near existing levels.

8. The routing of export water through Lake Berryessa would result in no apparent benefits to the lake aside from an improvement in the mineral quality of the lake water.

9. The mineral quality of water which would be impounded in the Glenn Reservoir Complex would be satisfactory for most beneficial uses.

It is clear that water quality problems must be anticipated and planned for regardless of which route is selected. It is also clear that additional study is needed to better define problems in the selected route and to develop solutions for these problems. This will be done in the next phase of the Advance

Planning Program with particular attention devoted to possible biological and temperature problems. Data developed during this phase will provide a more complete basis for water quality management.

The need for more information regarding sediment became apparent during the course of this study. Information is needed not only on the total sediment load that will be entering the proposed impoundments, but also where the sediment will settle out within the impoundments. It appears, for instance, that due to the location of the tunnels, that problems may develop due to sediments isolating or plugging the tunnel entrances. In view of this, it is recommended that studies be undertaken to determine the pattern of sediment deposition within the reservoirs.

CLEAR LAKE ROUTE

Water which would be diverted from English Ridge Reservoir to Clear Lake will consist primarily of drainage from the Upper Eel River above Van Arsdale Dam. Due to the location of Garrett Tunnel and the relative magnitude of diverted Middle Fork Eel River flow and Upper Eel River flow, most of the water pumped to English Ridge Reservoir from the Middle Fork will not reach the entrance to Garrett Tunnel. The quality of the water exported via Clear Lake will therefore be primarily that of Upper Eel River water from above Van Arsdale Dam. In any case, the quality of Upper Eel River water and Middle Fork Eel River water is very nearly the same, so that the water quality evaluation of the Clear Lake Route is applicable to both English Ridge and Middle Fork diversions.

Water Quality at Garrett Tunnel

The following is a summary of the quality of the water which would be diverted from English Ridge Reservoir to Clear Lake, at the waters point of entrance into Garrett Tunnel.

Mineral Quality

Monthly samples have been collected from the Eel River at the Potter Valley Power House tailrace since 1951. The following tabulation summarizes significant mineral quality characteristics at this location:

Characteristic	Range	Median
Specific Conductance (Micromhos)	95-285	140
Hardness (ppm as $CaCO_3$)	42-133	60
Boron (ppm)	0.0-1.5	0.3
Percent Sodium (percent)	6-17	14

The narrow range in concentrations of total dissolved solids, as evidenced by specific conductance, is due to regulation by Lake Pillsbury which tends to mix the more mineralized water from low flows with the less mineralized water from high flows. Because regulation has occurred above Garrett Tunnel, the values given above are more representative of the water quality that will be diverted than they would be if no storage effects were involved.

Although a boron determination of 1.5 ppm was made, such high concentrations rarely occur, and the median value of 0.3 ppm is within the limits of a Class I irrigation water.

Temperature

The operation of English Ridge Reservoir will have an important effect on the water temperature at any given elevation within the reservoir. If no water is withdrawn from a reservoir over a period of a year, a given temperature profile will exist in the reservoir, depending on the time of year. The quantity of water withdrawn, and the elevation from which it is withdrawn, both have an effect on modifying the "steady state" temperature profiles which would exist if the reservoir was not operated. Knowledge of water temperatures needed at a specific time, and the ability to select water from a reservoir elevation which will provide water of the desired temperature, are fundamental to temperature control through reservoir operation.

The temperature of water diverted through Garrett Tunnel to Middle Creek will not be critical as far as the beneficial uses of Middle Creek are concerned. In addition, it will be shown later that the temperature of Clear Lake will not be significantly modified by the importation of Upper Eel River water.

The following tabulation shows probable temperature ranges at Garrett Tunnel. These ranges were arrived at using temperature data from Lake Mendocino, Lake Pillsbury, and Ruth Reservoir. The tabulation also shows the average temperatures of the existing flow in the Eel River below Scott Dam.

Month	Garrett Tunnel Temperature Range Within Depth Range of 0-100' °F	Below Scott Dam Average Temperature of Unimpounded Flow - °F
January	43	43
February	50-42	42
March	53-43	44
April	55-46	53
May	58-49	57
June	68-50	58
July	73-52	58
August	70-53	58
September	68-53	64
October	60-55	61
November	57	52
December	46	46

Turbidity

The potential turbidity problems related to Eel River impoundments are indicated by what has happened at Lake Mendocino on the East Fork of the Russian River. Upper Eel River water is presently discharged through P. G. & E.'s Potter Valley Power House into the East Fork of the Russian River, thence into Lake Mendocino.

The following tabulation shows the levels of turbidity entering the East Fork Russian River from the Eel River, the levels of turbidity in the East Fork Russian River above Lake Mendocino, and the levels of turbidity being discharged from Lake Mendocino through the bottom withdrawal intake tower.

Date	Potter Valley Power House Tailrace JCU *	East Fork Russian River above Lake Mendocino JCU*	Lake Mendocino Discharge JCU*
11-4-64	100		
11-13-64		65	100
12-20-64	160	100	
12-22-64	2000	2900	
1-5-65		5400	450
1-6-65	1700	1400	
1-25-65	600	330	380
2-1-65	400	270	320
3-8-65	250	210	220
3-25-65	120	100	190
4-26-65	170	80	100
6-22-65	40	30	65
8-26-65	20	25	30
9-20-65	2	10	10
11-18-65	400	250	20
12-28-65	240	1200	110

* Jackson Candle Units

The above data clearly shows the effect of the storm which began on the night of December 21, 1964. During the storm period a significant decrease in turbidity occurred in the East Fork Russian River due to the impoundment of water in Lake Mendocino. Following the storm, however, the turbidity level in the inflowing water to Lake Mendocino dropped below the level of turbidity in the impounded water. The same effect will occur in English Ridge Reservoir although not necessarily of the same magnitude.

Ruth Reservoir, located on the Mad River, is similar in geometry to the proposed English Ridge Reservoir above Garrett

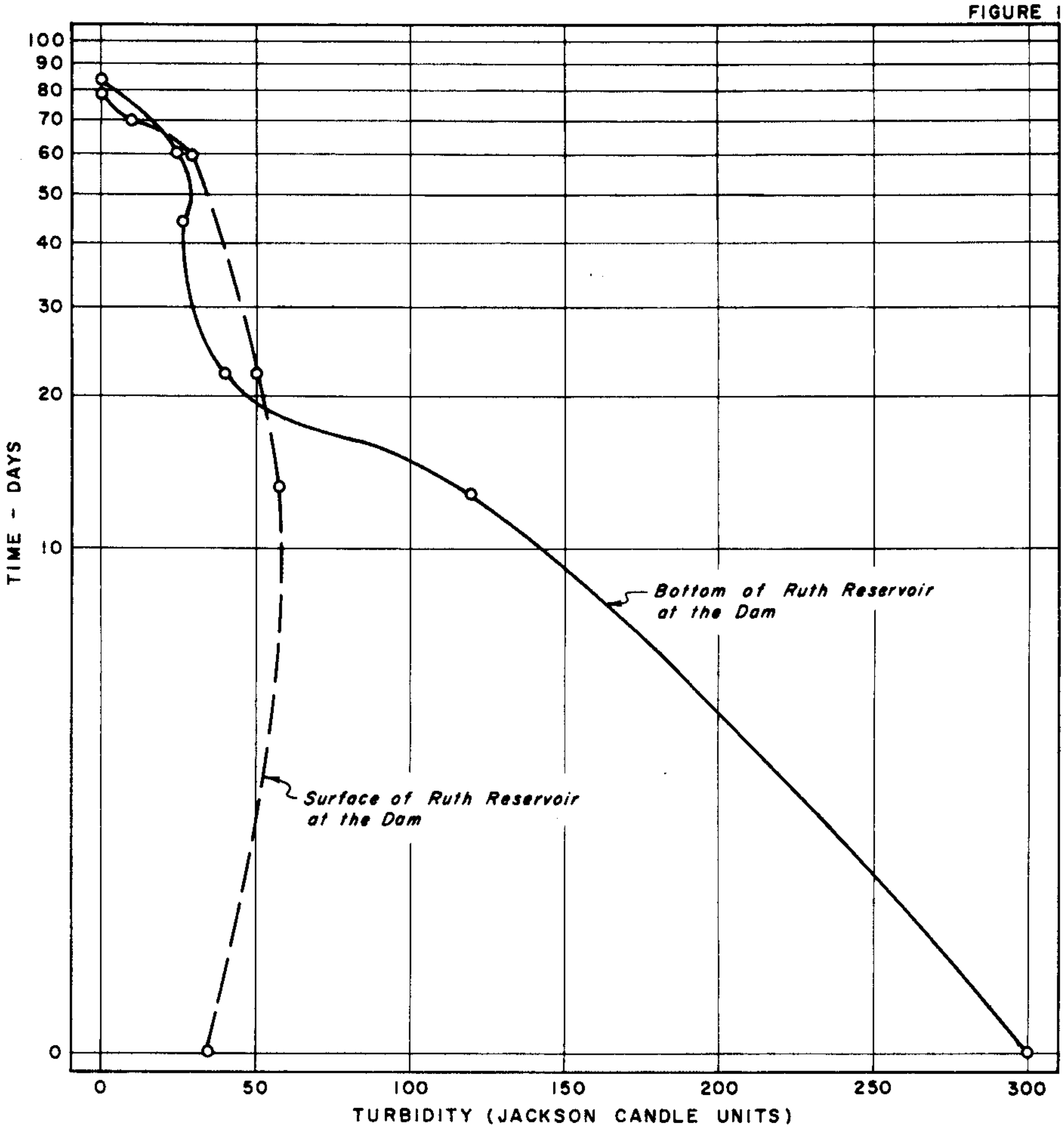
Tunnel. The geology and topography of the two watersheds are also similar, so that turbidity production is believed to be comparable. The highest measured level of turbidity in water discharged through the bottom outlet of Ruth Reservoir was 500 JCU.

The elevation at which water is withdrawn from a reservoir will have an effect on the level of turbidity in the water withdrawn. At the time when 500 JCU was measured near the bottom of Ruth Reservoir, 220 JCU was measured at the surface.

Figure I shows levels of turbidity at the bottom and at the surface of Ruth Reservoir for a single storm. It is apparent from Figure I that during the first days following a storm, a considerable reduction in turbidity can be obtained by taking water from near the surface of the reservoir.

These data indicate that if water diverted through Garrett Tunnel is taken from the bottom of English Ridge Reservoir, the maximum level of turbidity in the export water may be expected to be in the range of 500 to 600 JCU, shortly following a storm. The length of time that the turbidity will persist, will depend to a great extent in the type and intensity of the storm which produces the turbidity. Persistance will also be affected by the water temperature and the wind.

The following tabulation indicates the approximate average level of turbidity which may be expected in water diverted from English Ridge Reservoir through Garrett Tunnel. The approximations are based on a bottom withdrawal to Garrett Tunnel.



TURBIDITY VARIATION IN RUTH RESERVIOR

Month	Turbidity Range
	JCU
November December January February March	25-500
April May	50-125
June July August September October	25-50

Turbidity levels which may be expected at the Garrett Tunnel entrance as the result of a single storm are tabulated below:

Length of time following a storm	Turbidity Level resulting from an average storm	Turbidity levels resulting from an intense storm
Days	JCU	JCU
0	300	500
10	180	500
20	50	400
30	30	300
40	27	175
50	26	125
60	25	110
70	5	100
80		100
90		100
100		100
110		80
120		50
130		40
140		35
150		30
160		25
170		20
180		20

Dissolved Oxygen

During the period from approximately the first of April to approximately the end of October a thermocline may be expected to exist in English Ridge Reservoir.

Organic decomposition will take place throughout the water mass. This will result in a decrease in the dissolved oxygen content of the water in the hypolimnion over this period due to a lack of oxygen replenishment below the thermocline. The dissolved oxygen level below the thermocline may reach zero, and hydrogen sulfide may be produced. Water discharging from the bottom outlets of Ruth Reservoir and Lake Mendocino has contained hydrogen sulfide.

Nutrients

The levels of nitrogen and phosphorus in the water of the Upper Eel River are sufficient to sustain biological productivity.

Monthly tests have been made for total phosphates and nitrates since January 1965. Prior to January 1965, semi-annual tests were made for total phosphates and nitrates beginning in May 1959.

Total phosphate levels have ranged during this period from 0.00 to 0.49 ppm with a median of 0.05 ppm. Nitrates have ranged from 0.0 to 3.4 ppm with a median of 0.6 ppm. These levels are above the minimum concentrations which are known to be essential to the production of plant life.

Iron and Manganese

These constituents are not expected to be a problem in water diverted from the Upper Eel River.

Analysis of a sample collected at Potter Valley Powerhouse on September 6, 1961, showed a manganese concentration of 0.26 ppm, which is considerably above the U.S. Public Health Service recommended limit of 0.05 for drinking water. Previous and subsequent analyses, however, have shown no significant concentrations of manganese in this water. The high concentration of manganese in September 1961 is believed to have resulted from the concentrating of manganese ions or compounds in Lake Pillsbury. This complex phenomenon is related to changes in concentrations of dissolved oxygen with depth, and is accelerated by biologic activity.

Middle Creek

Water from Garrett Tunnel will be discharged to Middle Creek which is a tributary to Clear Lake.

Middle Creek is intermittant in its lower reaches during most years. Its beneficial uses include a limited resident trout fishery near its headwaters where flow is present throughout the year, some stock watering, and limited use for irrigation.

Water from Middle Creek and Scotts Creek, which joins Middle Creek below the proposed Garrett Tunnel outlet, is calcium-magnesium bicarbonate in type. The water is of excellent mineral quality with specific conductivity ranging from 116 to 260 micromhos, hardness from 58 to 118 ppm, boron from 0.00 to 0.55 ppm and percent sodium from 14 to 25 percent. The median boron concentration is 0.18 ppm. Two samples from Middle Creek have contained concentrations of total phosphate of 0.08 ppm and 0.04 ppm.

No significant change in the mineral quality of water in Middle Creek is anticipated due to the introduction of Upper Eel River water.

Clear Lake

Since the geometry of Clear Lake has an important bearing on water quality, the following paragraphs will be devoted to a physical description of the lake.

The Lake

Clear Lake is the largest natural lake entirely within California. The length along its long axis, from Rodman Slough Bridge to its outlet at Cache Creek, is approximately 18 miles. It is eight miles wide at its widest part. When the lake is at a level of 7.5 feet on the Rumsey gage the total area of the lake is 68.5 square miles, with a shoreline approximately 71 miles long and an average depth of 26 feet. The maximum depth of 60 feet occurs in the Oaks and Lower Arms.

The lake is not fed by perennial streams, thus its level is determined by runoff from precipitation. The lake's elevation, therefore, follows the same seasonal pattern as the precipitation. The level of the lake is now controlled by an impounding dam that was constructed on the Cache Creek outlet in 1915 by the Yolo Water and Power Company. The purpose of the dam is to retain winter runoff for release during the irrigation season. The dam is operated under a court decree that allows the lake to fluctuate between zero and seven and one-half feet in elevation based on an established reference plane referred to the "Rumsey Gage". This fluctuation occurs mostly during the irrigation season, starting out at the maximum seven and one-half feet at the beginning of the season, and dropping to near zero at the end of the growing season in September, before the winter rains begin. The natural level of the lake is controlled by a natural barrier in the Cache Creek outlet called the Grigsby Riffle. This riffle is approximately three and one-half feet below zero on the Rumsey Gage.

Clear Lake can be considered as consisting of three bodies of water, with the Upper Arm being separated from the Oaks Arm (East Arm) and the Lower Arm by a natural constriction called the "Narrows". The Upper Arm is defined as that portion of the lake north of an east-west line drawn between the eastern tip of Buckingham Point and the southern tip of Glenhaven Point. The Oaks Arm is defined as that part of the lake east of a north-south line drawn from the southern tip of Glenhaven Point to the western tip of Sulphur Bank Point. The Lower Arm is the remainder of the lake to the outlet of Cache Creek near Indian Island.

The Upper Arm, the largest of the three arms, is approximately circular, having an extreme length of ten miles and an extreme width of eight miles. It has a water surface area of approximately 31,500 acres (49 square miles), about 72 percent of the total area of the lake. The average depth of the Upper Arm with the lake level at 7.5 on the Rumsey Gage is a little more than 23 feet, with a total storage capacity of more than 730,450 acre-feet of water [1/]. This is approximately 63 percent of the total volume of the lake.

1/ Obtained by planimetering contours from U. S. Coast and Geodetic Survey hydrographic map of Clear Lake dated January 1949.

The Oaks Arm is the smallest of the three arms and has the smallest drainage area surrounding it. Trending in an east-west direction, it is approximately four miles long and a mile and one-half wide at its widest point. It has a water surface area of approximately 3,100 acres or seven percent of the total area of the lake. Though it has a much smaller area than the other two arms, it is deeper, having an average depth of approximately 36 feet. The total volume of the Oaks Arm is approximately 11,400 acre-feet, or ten percent of the total lake.

The Lower Arm is the outlet for Clear Lake, being drained by Cache Creek which starts just south of Indian Island. This arm is irregular with the axis of the arm trending in a northwest-southeast direction. It is approximately eight and one-half miles long and at its widest point, between Konocti Bay and Pirates Cove, approximately two and one-half miles wide. It has about 9,200 acres of surface area, which is 21 percent of the total area of the lake, with an average depth of approximately 34 feet. The north end of this arm is deepest, sloping upward to the shallow outlet at Cache Creek. The total storage in the Lower Arm is approximately 311,200 acre feet, or 27 percent of the total volume of the lake.

TABLE I

Summary of Surface Area, Volume, Average Depth, and Shoreline of Each Arm of Clear Lake

	Upper Arm	Oaks Arm	Lower Arm	Total
Surface Area in Acres	31,500	3,100	9,200	43,800
Percent of Total	72	7	21	
Total Volume of Water in Acre-Feet	730,450	111,400	311,200	1,153,050
Percent of Total	63	10	27	
Average Depth in Feet	23.2	36.5	33.8	
Total Length of Shoreline in Miles	35	12	24	71
Percent of Total	50	17	33	

<u>Mixing of Clear Lake Waters</u>

Water diverted from the Eel River to Middle Creek will enter Clear Lake through Rodman Slough. The water will then pass through the Upper Arm of Clear Lake which constitutes, as is shown above, 62 percent of the total lake volume and 72 percent of the total lake area. The amount of mixing which will occur between the lake water and the diverted water in this large shallow portion of Clear Lake will have an important effect on water quality.

A good demonstration of mixing of inflowing waters with the Lake waters occurred during the winter floods of 1964-65. Large amounts of precipitation in December caused more than 500,000 acre-feet of runoff to Clear Lake within a short period of time. Three-fifths of this amount (300,000 acre-feet) was released through the Clear Lake dam at the maximum allowable rate of 10,000 acre-feet per day, the remainder being retained in storage. A large portion of this inflow entered the lake through two drainages: (1) Rodman Slough, which combines the drainage of Scott, Middle and Clover Creeks, and (2) Kelsey Creek.

Two sets of temperature profiles were made in the lake across the expected area of influence of Rodman Slough. This was done to determine if stratification or channeling of the inflowing water was occurring, or if the waters were mixing.

One of these surveys was made in the latter part of November 1964, after normal seasonal inflow had started. The second survey was made in January 1965, about one month after the large inflow had occurred.

Both of these surveys showed temperature differences of about $2^{o}F$ between surface and bottom near the mouth of Rodman Slough, but with decreasing differentials at greater distances from the inflow. At Station 6, which is three miles from Rodman Slough, the temperature of the lake water was uniform from top to bottom.

Another example of the mixing of inflowing water is evident from specific electrical conductance (EC) values determined at the same time at various stations.

Before the inflow began, EC values at all stations were fairly uniform at about 325 mmhos, but the EC value of inflowing water, as measured at Rodman Slough, was only 75 mmhos.

Within 4 or 5 months after inflow began, the EC values at all stations were about equal, showing that the inflowing water had become thoroughly mixed with the lake water.

Visual observations of the inflow were made from an airplane. This was possible because the inflowing waters were carrying light colored sediments that contrasted with the turbid lake waters. These observations revealed the incoming water from Rodman Slough to be visually identifiable for approximately one-half mile from Rodman Slough on a projection of the incoming current direction. The currents that existed in the lake at that time began to overcome the initial inflow velocity and started dispersing the inflowing water in an easterly direction until the inflow was no longer identifiable within one or two miles of entry.

Inflow from Kelsey Creek was just as easily identified, but the currents that existed in the lake near the inflow were able to overcome the inertia of the inflowing water within four or five hundred yards of entry and turned the inflow in an easterly direction parallel to the shore until it dispersed and lost its visual identity approximately one mile from entry.

Wind Effects

The currents are caused by winds, which are the biggest source of energy for movement of water within the lake. To determine the wind forces in the Clear Lake area, data on wind direction and velocity were collected in 1965.

Recording anemometers and wind direction instruments were installed at two locations; one at the end of the Lake County Mosquito Abatement District pier in Lakeport, and the other on a private pier in Glenhaven, opposite Buckingham Point. These instruments were in operation from February to July and from October to December.

It should be noted that the maximum velocities that could be recorded with these instruments was 20 miles per hour, therefore reported high velocity values based on records from these instruments would probably be less than the actual high values.

The wind data collected show that the highest velocities in the Clear Lake area occurred during the spring, with the Glenhaven area having overall higher average velocities than the Lakeport area. The following tabulation gives the average daily and weekly wind velocities at these two stations. The prevailing winds are westerly and northwesterly.

Lakeport

	Spring 1965		Fall 1965	
	High Avg. Velocity	Low Avg. Velocity	High Avg. Velocity	Low Avg. Velocity
24 hour	20+	1.9	7.0	0.5
168 hour	17.2	2.6	3.0	1.1 (200 hrs.)

Glenhaven

	Spring 1965		Fall 1965	
	High Avg. Velocity	Low Avg. Velocity	High Avg. Velocity	Low Avg. Velocity
24 hour	19.9	3.2	15.3	1.4
168 hour	16.6	6.8	9.3	3.3 (200 hrs.)

Hutchinson in his "Treatise on Limnology" pointed out that limnologists determined that winds with velocities of 300-700 cm/sec (7-16 mph) exerted forces of 0.65 to 6.3 dynes/cm^2. The lower values are in accordance with marine experience and laboratory investigation.

The work required to create currents and turbulent motion, leading to mixing and the distribution of the summer heat income in a first class lake corresponds to an average force of about 0.02 dynes/cm^2. If the larger figure 700 cm/sec were used to create the smallest force of 0.65 dynes/cm^2, then the smallest daily average velocity recorded of 0.5 mph is sufficient to create currents in Clear Lake.

From this information it is logical to assume that wind induced currents are nearly always present.

Any water introduced to Clear Lake through Rodman Slough cannot leave the lake until it travels the nine miles of the shallow Upper Arm and then passes through the "narrows" and migrates to the Lower Arm, all the while being subjected to the mixing action of the wind induced currents.

Because of these conditions, it is doubtful that stratification or channelization of imported water will take place for extended periods of time.

Subsequent analyses of the water quality effects of diverting Upper Eel River water through Clear Lake will, therefore, be based on the premise that complete mixing of the lake water, and the diverted water, will occur in the Upper Arm of Clear Lake.

Existing Hydrology of Clear Lake

There is one more item to be considered that would have an influence on what would happen to any water imported to Clear Lake and this is the quantity of water entering and leaving the lake each year.

There are three sources of inflow to Clear Lake; (1) runoff from precipitation, the major source, (2) subsurface flow from ground water, and (3) irrigation return and other waste flow.

Though there are some extensive geologic formations surrounding the lake that contain ground water, there is no evidence to show that water from these formations feeds the lake. Either the aquifers do not extend under the lake, or the thickness of the sediments of the lake bottom prevents any large scale interchange.

Soda Bay is the only known area where springs flow to or within the lake. The water coming from these springs is warm and highly mineralized. In numerous places throughout the lake, springs appear to be bubbling up; but they are actually gas vents that do not bring water into the lake.

Reclamation districts which have been created near the Upper Lake area to reclaim low lying land adjacent to Rodman Slough pump all of their irrigation return flow and drainage water to the lake. No measurable flows have been observed in drainage from Big Valley and Scott Valley.

The estimated average yearly inflow to Clear Lake from runoff is approximately 445,000 acre-feet. More than 70 percent of the total drainage area contributing this volume of inflow is tributary to the Upper Arm of the lake and is drained by six major streams: Kelsey Creek, Adobe Creek, Highlands Creek, Scott Creek, Middle Creek, and Clover Creek. Gaging stations have been established on all of these.

These gaging stations measure the runoff from approximately 155 square miles of drainage area (30 percent of the total drainage area) which contributes approximately 45 to 50 percent of the total inflow to the lake.

As was pointed out earlier, the storage capacity of the lake at an elevation of 7.53 feet on the Rumsey Gage is 1,150,000 acre-feet. The lake level is controlled by a dam, operated under a court decree, that will not allow the level of the lake to fall below "0" on the Rumsey Gage. At this elevation there is 842,000 acre-feet in storage in the lake. The 20 year average discharge from Clear Lake is 216,000 acre-feet. It has been estimated that evaporation from Clear Lake area accounts for 229,000 acre-feet loss each year, which would mean an average yearly change in storage of 445,000 acre-feet.

It would appear, from this information, that even under the most extreme runoff conditions there is not enough inflow to Clear Lake to completely flush or evacuate all of the water in the lake. This means that some of the water presently entering the lake through Rodman Slough remains in the lake for at least one year and can remain for as long as three years.

Mineral Quality

The following tabulation summarizes and compares significant mineral characteristics contained in the water of Clear Lake and the Upper Eel River:

	Range *		Median *	
Characteristic	Eel River	Clear Lake	Eel River	Clear Lake
Specific Conductance	95-285	187-358	140	262
Hardness	42-133	82-158	60	117
Boron	0.0-1.5	0.1-1.23	0.3	0.73
Percent Sodium	6-17	13-19	14	16

* Specific conductance in micromhos, hardness and boron in ppm, and percent sodium in percent.

Quality characteristics vary considerably from place to place in Clear Lake. The above data for Clear Lake was obtained from a monitoring station located at Lakeport and represents a summary of analyses of 150 samples. The Eel River data were obtained from samples collected at the Potter Valley Powerhouse tailrace.

The above data shows that the Eel River water is Class I for irrigation. Clear Lake water is Class II for irrigation due to the water's boron content. A separate section will be devoted to boron later in this report.

Although the Eel River water is of better mineral quality, both Eel River water and Clear Lake water would be considered to be of excellent mineral quality except for the boron content of Clear Lake.

As Eel River water journeys through Clear Lake from Rodman Slough to the outlet, mixing will cause the water to lose its chemical identity and the dissolved solids content will increase due to the concentrating of the water by evaporation and greater length of contact time with minerals or chemicals that are exposed to it.

During the first year of the Eel River diversion, the water leaving Clear Lake will be essentially of the same mineral quality that exists at present. After approximately two to three years of diversion, however, Clear Lake water will have been largely replaced by Eel River water, chemical equilibrium will have been established, and the influence of the importation of higher quality Eel River water will be reflected in Clear Lake. The resultant effect will be an improvement in Clear Lake mineral quality and a degradation of imported Eel River water quality.

The following tabulation indicates the approximate resultant mineral quality of the water that will be discharging from Clear Lake, after several years of receiving diversions from the Upper Eel River:

Characteristic	Median
Specific Conductance (Micromhos)	208
Hardness (ppm)	92
Percent Sodium (percent)	15

These values were arrived at using an average yearly diversion from the Eel River of 1,046,000 acre-feet and an average yearly normal discharge from Clear Lake of 268,000 acre-feet.

Boron

Boron is the only mineral constituent that limits or significantly affects the use of Clear Lake water for beneficial use. The boron content in the lake is sufficient to place the water in Class II for irrigation.

Determinations of boron concentrations in Clear Lake have been made since February 1953, on samples collected on a monthly basis at the Lakeport City pier and at the outlet of Clear Lake. Though these determinations show the concentration of boron reaching as high as 2.2 ppm, evaluation of physical conditions near the sampling station and climatological conditions at the time the sample was collected indicate that some of the extremely high and low values are not representative of the actual boron concentrations in the lake water.

The boron concentrations in the outflowing waters during the six months of irrigation releases are probably more indicative of the actual concentrations of boron in the lake water. For the 12 years of records available, the lowest boron concentration determined during the six month period beginning in May and ending in October was 0.3 ppm. The highest value was 1.2 ppm.

The following tabulation shows the boron concentrations and the frequency with which they occurred:

Boron in ppm	Frequency of Occurrence
.3	1
.4	0
.5	3
.6	8
.7	2
.8	16
.9	17
1.0	17
1.1	3
1.2	5

The median value and average value are both 0.9 ppm.

From these data, it can be expected that under existing conditions for releases during the irrigation season, the concentrations will be about 1.0 ppm, with no concentration above 1.2 ppm, unless extended periods of low inflow occur.

Though there are several possible sources of boron in the vicinity of the lake, no single source has been found that contributes boron in amounts sufficient to raise the overall levels in the lake.

Eel River water will enter Clear Lake with a boron content of approximately 0.17 ppm. This concentration of boron represents a weighted average and, therefore, reflects impoundment effects whereas a straight median does not. During the first year of project operation the boron concentration in water discharged from Clear Lake may reach 1.2 ppm. Following displacement of Clear Lake water with Eel River water, however, the median boron content of the water discharged from Clear Lake may be expected to be approximately 0.3 ppm. This would place the water well within the 0.5 ppm boron limit for Class I irrigation water. The following tabulation shows the boron concentration expected in the discharge from Clear Lake, assuming varying quantities of import water:

Annual Diversion from Eel River 1,000 A/F	Boron Concentration ppm
1040	0.3
500	0.4
200	0.6
100	0.7

Temperature

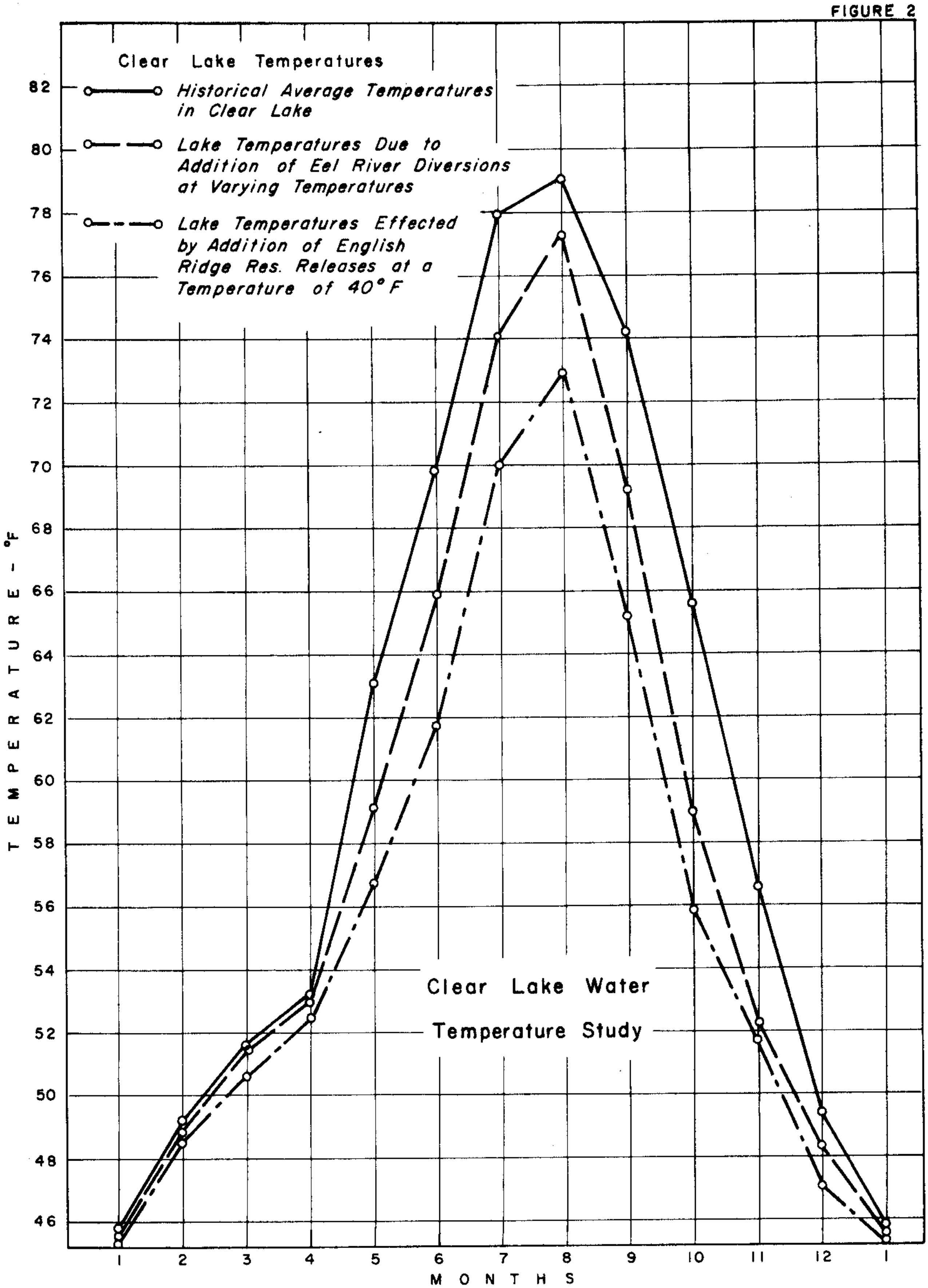
It was previously shown that complete mixing may be expected between imported water and Clear Lake water in the Upper Arm of Clear Lake. This condition was utilized in estimating the change in lake temperature due to importation of Eel River water.

Two computations were made for temperature prediction. First, it was assumed that the temperature of the imported water would be 40° Fahrenheit throughout the year. This, of course, is not realistic, but it does represent an extreme case. In the second computation the temperature of the imported water was assumed to vary in accordance with the minimum of the temperature range shown in the tabulation on page 7 . In both cases the quantity of water imported was based on a period of high flow.

Figure 2 shows the temperatures expected to result in the Upper Arm of Clear Lake due to the inflow of Eel River water according to one operation schedule.

These temperatures will not adversely effect the existing beneficial uses of Clear Lake. The reduction of the high summer temperatures will be of benefit to the lake's fishery. It is not anticipated that the temperature reduction will significantly modify the primary productivity of the lake, although a slight decrease could occur due to the temperature change. This also would be of benefit to the lake.

As the water moves from the Upper Arm to the outlet, it will increase in temperature. The temperature discharging from the lake should not be significantly different than at present.


Clear Lake Temperatures
Historical Average Temperatures in Clear Lake
Lake Temperatures Due to Addition of Eel River Diversions at Varying Temperatures
Lake Temperatures Effected by Addition of English Ridge Res. Releases at a Temperature of 40° F
Clear Lake Water Temperature Study
TEMPERATURE - °F
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
1 2 3 4 5 6 7 8 9 10 11 12 1
MONTHS

Turbidity

Runoff and wind induced currents keep the shallow Upper Arm of Clear Lake turbid most of the year.

During 1964-65, 106 turbidity measurements were obtained from the Upper Arm of Clear Lake. The turbidity values varied from a low of 15 JCU to a high of 350 JCU. Approximately 80 percent had values of 100 JCU or less, and 55 percent had values of 50 JCU or less.

The following tabulation shows the range in turbidity values obtained each month, from July 1964 to June 1965, at two stations in the Upper Arm of Clear Lake. One of these stations (Station No. 4) is located at a point approximately 2 miles directly out from the outlet of Rodman Slough. The other station (Station 13) is located approximately 7-1/2 miles from the outlet of Rodman Slough.

Month	Turbidity - JCU Station 4	Turbidity - JCU Station 13
July	30-100	26-60
August	26-70	20-60
September	25-105	42-60
October	60-82	50-82
November	39-85	40-100
December	44-72	31-188
January	72-134	188-330
February	134-200	220-315
March	135-158	136-220
April	84-140	50-136
May	29-84	15-69
June	29-30	16-36

The levels of turbidity expected in the water imported from the Upper Eel River are shown on page 11.

During the period November through March, rainfall will occur on the Upper Eel River watershed, causing the water in English Ridge Reservoir to become turbid. The storm pattern for a given year will determine the level of turbidity at a given time.

If a storm of high intensity were assumed to occur during February, a comparison of the resulting turbidity level in the imported water with the normal turbidity level in Clear Lake would show that the turbidity in the imported Upper Eel River water may exceed the turbidity level normally in Clear Lake by more than 300 JCU. Following the storm, the turbidity level in the imported water would exceed the turbidity level in Clear Lake for approximately 40 days. Of course, another storm during the 40 day period would actuate a new turbidity cycle.

During the months of April and May the turbidity in the imported water may be expected to be nearly at the same level as normally exists in Clear Lake during this period.

In the summer, June through October, the turbidity level normally in Clear Lake is likely to be above the level in the imported Upper Eel River water.

An increase in the turbidity level in the Upper Arm of Clear Lake during portions of the period November through March would not affect the lake's existing known beneficial uses.

In April and May no substantial difference in turbidity is expected between the imported water and the turbidity level normally in the lake water; however, portions of the lake containing water which entered the lake during the storm period would be more turbid than normal.

During the summer, a decrease in turbidity may occur over what is normally in the lake in an area extending out from Rodman Slough. This would occur due to the imported water being clearer than the lake water. The size of the area of the lake that would be affected by the clearer water would depend to a large extent on the degree of mixing between the imported water and the lake water due to the action of the wind and the hydraulics of the inflow. The effect of a reduction in the turbidity level would be an increase in the depth of the euphotic zone, the lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur because of ineffective light penetration. This increased zone would then allow greater biological activity throughout the effected area. The result could be an acceleration of aquatic growths, especially in the shallow areas along the lake's edge and into Rodman Slough. Appropriate control measures may be necessary, as part of the projects operation program, to cope with this possible problem.

From the foregoing, it is concluded that the turbidity content of the water imported into Clear Lake probably would not result in an improvement in Clear Lake water quality, nor would it cause water quality problems that would be a detriment to utilizing Clear Lake as an export route.

Dissolved Oxygen

The dissolved oxygen content of Clear Lake varies from supersaturation to zero. It varies with location, depth, time of year, and time of day. It is affected by temperature, the activity of aquatic biota, the chemical composition of the water, the organic content of the water, climatological conditions, and hydraulics. Fish kills have been reported in Clear Lake due to a lack of dissolved oxygen.

The importation of Upper Eel River water probably would not modify significantly the existing dissolved oxygen content in the lake. The magnitudes of the forces which determine the present oxygen levels will, in all probability, remain essentially the same.

Water discharging from the lake will pick up dissolved oxygen, if the level is below saturation, through aeration as it flows downstream. The beneficial uses of the water in channels receiving releases from Clear Lake would not be adversely effected due to an initially low dissolved oxygen level in the water released from the lake.

Nutrients

Clear Lake is rich in nutrients and is ideal in other aspects for the growth of plankton, such as algae and water fleas. The growth of plankton is the lake's most serious water quality problem.

There are a number of factors which contribute to the lake's productivity. These include the geometry of the lake, the climate, and the availability of nutrients necessary for the growth of aquatic biota.

Like any other living matter, plankton need nutrients to live. Generally, those chemicals needed for plant and organism growth that are required in more than trace amounts are carbon, hydrogen, oxygen, nitrogen, phosphorous, potassium, sulfur, calcium, and magnesium. Micronutrients, nutrients needed only in trace amounts, include iron, manganese, cobalt, molybdenum, boron, zinc, and copper.

The principal nutrients needed by algae to produce new protoplasm are nitrogen and phosphorous, which they take from solution during their growth. A few species of algae are capable of taking nitrogen from the air.

Studies have indicated that in order for algae growth to occur or proceed, nitrogen, phosphorous, and iron must be present in the water at levels above the following concentrations:

Nitrogen - - - - - 0.1 ppm

Phosphorous - - - 0.01 ppm

Iron - - - - - - - > 0 ppm

The range of nitrogen and phosphorous levels found in Clear Lake are shown in the following tabulation:

Ammonia As N (ppm)	Nitrate As N (ppm)	Organic Nitrogen As N (ppm)	Total plus Organic PO_4 (ppm)
0.01-0.32	0.1-5.8	0.2-1.5	0.10-0.54

These levels are considerably above the minimum concentrations needed to support algae growth.

Eel River water contains a median level of nitrates of 0.6 ppm and a median level of total phosphates of 0.05 ppm. It has been shown that, if assets of inorganic nitrogen and phosphorus exceed 0.30 and 0.01 ppm respectively, at the start of the active growing season, a season with nuisance blooms could follow. Iron, and the other elements which comprise the total nutrient picture will be present in the Eel River water at sufficient levels to sustain aquatic life. In view of the above, it is not expected that the importation of Eel River water will modify the nutrient levels in Clear Lake significantly. As was previously indicated, other environmental factors which effect productivity include temperature and turbidity.

It has been shown that the temperature of the Upper Arm of Clear Lake will be lowered slightly by the introduction of Eel River water. The magnitude of the decrease, however, is not expected to be large enough to significantly modify the existing ecology of the lake's plankton population.

The levels of turbidity in the lake may be slightly higher than they normally would be during the early part of summer due to the inflow of turbid Eel River water during the winter and early spring months.

Any reduction in the euphotic zone would decrease the biologic activity. There, therefore, would be a reduction in plankton growth over what would normally occur in the lake as long as the level of turbidity in the lake remains above the normal level for a particular time period.

In summary, the overall productivity of Clear Lake may be modified by the introduction of Eel River water. The magnitude of productivity would probably be decreased slightly, together with a modification of its time sequence. Neither of these changes however, are expected to be of significant magnitude to effect the beneficial use of the lake. A decrease in productivity in the lake is desirable.

Quality of Water Exported from Clear Lake

Export water leaving Clear Lake will either flow via Cache Creek to the Sacramento River, or will be diverted from Cache Creek, near the outlet of Clear Lake, to Putah Creek drainage and thence to the Sacramento River.

The quality of the water leaving Clear Lake will be summarized prior to discussing the quantity aspects of each of the possible conveyance routes from Clear Lake to the Sacramento River.

Mineral Quality

Export water leaving Clear Lake after a few years, is expected to have the following significant mineral characteristics:

Characteristics	Median
Specific conductance	160 micromhos
Hardness	72 ppm
Percent Sodium	14 percent
Boron	0.3 ppm

Water of this mineral quality is satisfactory for nearly all beneficial uses.

Temperature

As was previously indicated, the temperature of the water leaving Clear Lake will be changed only slightly from its pre-project levels. The top curve of Figure 2 shows expected water temperatures at the outlet of Clear Lake.

Turbidity

Based on the volume of Clear Lake and the quantity of Upper Eel River water diverted to it, the theoretical detention time of Upper Eel River water in Clear Lake is approximately one year.

During a period of this length, or even shorter, nearly all turbidity entering Clear Lake from the Upper Eel would be expected to settle out before reaching the lakes outlet.

The level of turbidity at the Clear Lake outlet would, therefore, most often be due to factors other than the effect of Upper Eel River water, such as plankton, for instance.

The following tabulation shows the ranges of turbidity expected in the water discharged from Clear Lake. These data were obtained from measurements made on water discharging from Clear Lake during 1964-65.

Month	Turbidity - JCU
January	50 - 90
February	45 - 80
March	25 - 45
April	20 - 35
May	15 - 50
June	10 - 30
July	10 - 50
August	6 - 35
September	35 - 80
October	45 - 65
November	10 - 45
December	10 - 50

These levels of turbidity will not be detrimental to the beneficial uses of the water which are foreseen at the present time.

Dissolved Oxygen

The dissolved oxygen level in the water discharging from the lake will vary. Water discharging from the lake will pick up dissolved oxygen, if the oxygen level is below saturation, through aeration as it flows downstream. Reaeration will occur within a relative short distance so that no problems due to low oxygen levels are anticipated in downstream waters.

Nutrients and Productivity

Export water leaving Clear Lake would be rich in nutrients. As long as the water is flowing, such as in a streambed, plankton growth would be suppressed. Plankton would undoubtedly thrive, however, at any point where the water is impounded. Attached forms of algae similar to those now found in the streams of the area will persist and may increase.

This doesn't necessarily mean that profuse algae blooms will occur throughout reservoirs receiving water from Clear Lake. Factors which will effect the growth of algae in these reservoirs include: the reservoir depth, size and geometry; water temperature; the nutrient levels in water from the reservoirs watershed; climatological conditions; the replenishment of the available nutrient supply from processes taking place in the reservoir; and the depth of the eutrophic zone.

Clear Lake to Sacramento River Via Putah Creek

Export water from Clear Lake could be routed to the Sacramento River via Putah Creek. It would be diverted from Cache

Creek a short distance below Clear Lake through a tunnel to Soda Creek in the Upper Putah Creek Basin. The water would then pass through the proposed Stienhart and Jerusalem Reservoirs and Powerplants, down the main stem of Putah Creek to Lake Berryessa and thence via Putah Creek to the Sacramento River.

The mineral quality of waters within the Putah Creek drainage is discussed in the following paragraphs.

Soda Creek Mineral Quality

Limited mineral data from Soda Creek indicate that the water is more mineralized than Clear Lake water. The water is hard and would have to be softened prior to use for domestic or industrial purposes. In addition, the boron level in Soda Creek water makes it unsuitable for most irrigation uses. The following tabulation shows levels of significant mineral constituents found in Soda Creek on April 9, 1952:

Specific Conductance	1460 micromhos
Hardness	552 ppm
Boron	3 ppm
Percent Sodium	33 percent

Putah Creek Mineral Quality

Putah Creek above Coyote Valley is of excellent mineral quality. The water is suitable for nearly all beneficial uses.

Between Coyote Valley and Berryessa Valley, Putah Creek receives inflow from Soda, Hunting, Butts, and Eticuera Creeks. As a result of this inflow, Putah Creek becomes considerably more mineralized. Even though more mineralized at Berryessa Valley, the water is of satisfactory mineral quality for most beneficial uses. Its hardness, however, has reached a level that would make treatment of the water necessary for some industrial uses, and desirable prior to use for domestic purposes.

The quality of Putah Creek varies with the flow, with better quality water during high flow periods and poorer quality water during low flow periods. The mineral quality of the water discharged at Monticello Dam is a composite of the two, due to mixing in Lake Berryessa. The following table shows ranges of quality characteristics for Putah Creek near Winters for the period 1952 to 1961. The effect of the completion of Monticello Dam in 1957, is clearly shown in Figure 3 .

TABLE 2

WATER QUALITY RANGES - PUTAH CREEK NEAR WINTERS

Item	Maximum of Record	Minimum of Record	Maximum - 1961	Minimum - 1961
Specific conductance (micromhos at 25°C)	568	146	365	316
Temperature in °F	84	43	66	43
Dissolved oxygen in parts per million	14.8	2.0	13.6	9.8
Percent saturation	142	22	130	91
pH	8.4	6.8	8.3	7.4
Mineral constituents in parts per million				
Calcium (Ca)	113	13	20	20
Magnesium (Mg)	70	13	26	26
Sodium (Na)	70	2.5	12	7.7
Potassium (K)	5.6	0.2	1.8	1.8
Carbonate (CO_3)	35	0	20	0
Bicarbonate (HCO_3)	448	73	195	144
Sulfate (SO_4)	79	8.6	15	11
Chloride (Cl)	50	2.0	12	4.2
Nitrate (NO_3)	2.7	0.0	0.4	0.3
Fluoride (F)	0.4	0.0	0.2	0.2
Boron (B)	1.7	0.00	0.3	0.0
Silica (SiO_2)	29	13	15	13
Total dissolved solids in parts per million	520	88	220	175
Percent sodium	28	6	13	9
Hardness as $CaCO_3$ in parts per million				
Total	371	67	168	156
Noncarbonate	55	0	11	1
Turbidity	1,000	0	10	1
Coliform in most probable number per milliliter	>7,000.	0.023	62.	0.046
Radioactivity in micro-micro curies per liter				
Dissolved alpha	0.43	0.00	0.35	
Solid alpha	1.02	0.00	0.17	
Dissolved beta	22.0	0.00	1.0	
Solid beta	3.80	0.00	0.0	

FIGURE 3

WATER QUALITY VARIATIONS

PUTAH CREEK NEAR WINTERS (STA. NO. 81)

The following tabulation shows ranges and medians of significant mineral characteristics of waters found in Putah Creek since 1957. These data are representative of the present mineral quality of water released from Monticello Dam.

Characteristic	Range	Median
Specific Conductance	263-868 micromhos	320 micromhos
Hardness	96-312 ppm	156 ppm
Boron	0.0-1.1 ppm	0.2 ppm
Percent Sodium	6-33 percent	12 percent
Chloride	4-40 ppm	7 ppm
Nitrate	0.6-2.8 ppm	0.4 ppm

The mineral quality of this water is satisfactory for nearly all beneficial uses.

Summary of Water Quality for Putah Creek Route

The water quality in the proposed Stienhart and Jerusalem Reservoirs would be similar to that of Clear Lake. The mineral quality of the water in these reservoirs may be degraded slightly by Soda Creek.

The reservoirs may be expected to have a relatively high productivity due to the impoundment of nutrient rich Clear Lake water. However, unlike Clear Lake, replenishment of nutrients to the eutrophic zone of Stienhart and Jerusalem Reservoirs would be restricted, due to the greater water depth. This factor would tend to lower production of bio-mass per unit of reservoir volume. A counter influence would be that Stienhart and Jerusalem Reservoirs would be less turbid than Clear Lake and, therefore, would have a eutrophic zone of greater depth. These two factors may tend to balance each other. It is probable that plankton growth would occur as the water passes through Stienhart and Jerusalem Reservoirs. These growths would remove nutrients from the water and thereby may decrease the "algae growth potential" of the water by making it less rich by the time it reaches Lake Berryessa.

The upper waters of Stienhart and Jerusalem Reservoirs will be warm, approximating the temperatures in Clear Lake. Their depth, however, will be sufficiently great for the formation of a thermocline during the period from approximately the first of April to approximately the end of October. This means that below a depth of approximately 50 feet, the water could remain at a temperature considerably below the temperature of the inflowing water during the summer months. This cool water from winter flows may be depleted fairly rapidly, depending on the rate of water withdrawal from below the thermocline. Based on available information, it does not appear that the operation of Stienhart and Jerusalem Reservoirs would be such that any substantial change in water temperatures would occur in streams receiving releases from them. Beneficial uses of these streams are therefore not expected to be modified due to temperature changes.

Export water entering Lake Berryessa would be fairly rich in nutrients at approximately the same temperature, and contain the same turbidity level as the present inflow.

It is likely that the export waters "algae growth potential", which is high at the outlet of Clear Lake, would have been reduced by its passage through Stienhart and Jerusalem Reservoirs.

One of the basic differences in Clear Lake and Lake Berryessa which would affect productivity is the water depth. In Clear Lake nutrients are almost constantly being added to the eutrophic zone by wind induced currents which stir and mix nutrient rich bottom sediments throughout the shallow profile of the lake. The depth of Lake Berryessa is too great for this to occur. Some problems with algae may be expected in the shallow portions of Lake Berryessa, near the upper end. It is not expected, however, that there would be any substantial modification in the lake's existing overall productivity.

The temperature of the water discharged from Lake Berryessa is relatively cold. During 1963-64 the temperature varied at the reservoir outlet from 59° Fahrenheit to 47° Fahrenheit. The outlet is 202 feet below the maximum water surface elevation. Temperature profiles run at Lake Berryessa during August, September, October, and November 1964 show that a thermocline existed at depths ranging from 25 feet to 50 feet - August through October. There was no thermocline by the middle of November. Temperatures below 125 feet in depth were less than 55° Fahrenheit during these months.

The routing of export water through Lake Berryessa would mean additional drawoff of cool water from the reservoir at the level of the existing outlet. Importation of water, therefore, could modify the temperature of the water normally released during the latter part of the summer and during the fall. The temperature effect would be primarily dependent upon the volume of water available at a given temperature and at the elevation from which releases are drawn. Insufficient data is available at this time to determine what the temperature change may be.

Turbidity in the inflowing export water may be above the level normally in Lake Berryessa during a portion of each year. A profile of turbidity levels taken at Lake Berryessa on July 29, 1965, ranged from 5 to 8 JCU from the surface of the reservoir to its bottom. Even if the turbidity level in the inflowing water is raised by 20 to 30 units due to the introduction of export water, it is not likely that a significant portion of the lake will be noticeably affected.

The inflow of export water to Lake Berryessa will generally improve its mineral quality. Using an inflow of import water of 1,046,000 acre-feet per year, the change in the mineral quality of water discharged from Lake Berryessa is indicated below:

Characteristic	Without Import Water Median	With Import Water Median
Specific Conductance	330 micromhos	200 micromhos
Hardness	156 ppm	93 ppm
Boron	0.2 ppm	0.3 ppm
Percent Sodium	12 percent	13.5 percent

Salt Routing Via Putah Creek

The effect of import water on the Sacramento River at its point of confluence with Putah Creek would be to increase the boron content of the river by 0.02 ppm, and increase the specific conductivity by 3.0 micromhos. Plate Number I presents a summary of the mineral quality changes for the entire routing, beginning at English Ridge Reservoir.

Clear Lake to Sacramento River Via Cache Creek

Surplus Eel River water could be diverted to the Sacramento River via Cache Creek. It is possible that a large reservoir, Wilson Valley or alternative, would be constructed on Cache Creek to reregulate the Eel River diversions.

Present Mineral Quality

Cache Creek is the natural drainage of Clear Lake. The mineral quality of Cache Creek in the uppermost reach is the same as the quality of outflow from Clear Lake.

The first major tributary to Cache Creek is North Fork Cache Creek. The two streams meet at a point approximately 8.8 stream miles below Clear Lake.

North Fork Cache Creek water is more mineralized than Clear Lake water. It is moderately hard, making softening desirable before use for domestic purposes. The median boron content of 2.6 ppm places the water in Class III for irrigation. The following tabulation shows ranges and medians of significant mineral characteristics found in North Fork Cache Creek water:

Characteristics	Range	Median
Specific Conductance (micromhos)	143-880	476
Hardness (ppm)	64-344	184
Boron (ppm)	.16-7.4	2.6
Chloride (ppm)	4-145	37
Percent Sodium (percent)	6-56	25

These data represent a summary of 60 analyses.

Approximately 13.0 stream miles below the confluence of Cache Creek and North Fork Cache Creek, Cache Creek is joined by Bear Creek.

The mineral quality of Bear Creek is poor. Undoubtedly Bear Creek is one of the major sources of detriment to the quality of water in Cache Creek. The following tabulation shows ranges of mineral constituents in waters of Bear Creek below Willow Springs bridge, based upon analyses of 17 samples taken from June, 1938 to November, 1939.

Constituent	Range	Average
Sodium	313-940 ppm	692 ppm
Chloride	403-1,500 ppm	894 ppm
Boron	9.4-34 ppm	21 ppm
Total dissolved solids	1,231-3,458 ppm	2,202 ppm
Percent sodium	58-81 percent	73 percent
Total Hardness	473-571 ppm	511 ppm

Summary of Water Quality for Cache Creek Route

The quality of export water in the uppermost reach of Cache Creek would be the same as the outflow from Clear Lake, which was summarized previously.

If a reregulatory reservoir were constructed on Cache Creek in the vicinity of the Wilson Valley site, the Upper Arms of the proposed reservoir would undoubtedly be subject to profuse algae blooms, particularly in the shallow portions. It is not expected, however, that algae conditions similar to those that occur in Clear Lake would develop in the deeper main body of the reservoir. The depth of the large reservoir should be sufficient to allow control of the temperature of water released, provided multiple level outlets are installed. The water released from the proposed reservoir would be turbid during a portion of each year. As far as can be seen at this time, turbidity will not be a major problem in the proposed reservoir or in Cache Creek.

It was previously shown that the mineral quality of Cache Creek drainage below Clear Lake is poor. By weighting the mineral constituents according to flow, the mineral quality resulting from impoundment can be estimated. This was done for boron and specific conductivity in North Fork Cache Creek water. The mineral quality of water which might be released from a proposed reservoir on Cache Creek was then determined by combining the quality of Clear Lake outflow with the weighted average quality of North Fork Cache Creek. The results indicate that water released from the reservoir would contain an average boron content of of 0.35 ppm and an average specific conductivity of 166 micromhos.

Salt Routing Via Cache Creek

The effect on the mineral quality of the Sacramento River of utilizing Cache Creek as an export route is shown in the following tabulation:

Characteristic	Present Median Level in the Sacramento River	Median Level in the Sacramento River Following the Addition of Export Water
Specific Conductance	152	154
Boron	0.04	0.09

Plate Number 1 presents a summary of mineral quality changes for the entire routing, beginning at English Ridge Reservoir. It can be seen that the export water will be of Class I for irrigation throughout the system and will generally be of excellent mineral quality, suitable for nearly all beneficial uses.

Gnats

For many years the people living in the vicinity of Clear Lake were plagued by a nuisance arising from the summer emergence of the Clear Lake gnat (Chaoborus Astictapus). At the present time this nuisance organism is largely controlled through the efforts of the Lake County Mosquito Abatement District.

The effect of the introduction of Eel River water on the district's existing control program is not known. It is safe to assume, however, that the gnats would exist in English Ridge Reservoir, and that they would be carried via the export water to Clear Lake. Since the timing of chemical treatment to coincide with a specific stage in the development of the gnat is very important to the control of the organism, the seeding of Clear Lake with transported gnats from English Ridge could upset the control program. Control of the gnats at English Ridge Reservoir would, of course, eliminate this problem. The total cost for the 1962 treatment program at Clear Lake was approximately $50,000.

GLENN ROUTE

Bulletin No. 136, "The North Coastal Area Investigation", outlines two alternative plans for diverting water from the Middle Fork Eel River to the Glenn Reservoir Complex: either (1) from Spencer Reservoir through Thomes Creek tunnel to Thomes Creek above Paskenta Reservoir, or (2) from Dos Rios Reservoir through the Dos Rios-Grindstone tunnel to Grindstone Creek above Rancheria Reservoir. The following water quality analysis of the Glenn Route was made for the Grindstone Creek route only. A trial salt routing for the Thomes Creek route is shown on Plate 2. Additional water quality analysis of the Thomes Creek route will be made when needed.

Water Quality at Grindstone Creek Tunnel

The following paragraphs describe the water quality conditions expected at the entrance to the Dos Rios Grindstone tunnel.

Mineral Quality

The mineral quality of the impounded water was determined by weighting the waters mineral content according to flow. The following tabulation shows the level of significant mineral characteristics expected in the impounded water.

Characteristic	Weighted Average
Specific Conductance	137 micromhos
Hardness	64 ppm
Boron	.06 ppm
Percent Sodium	10 percent

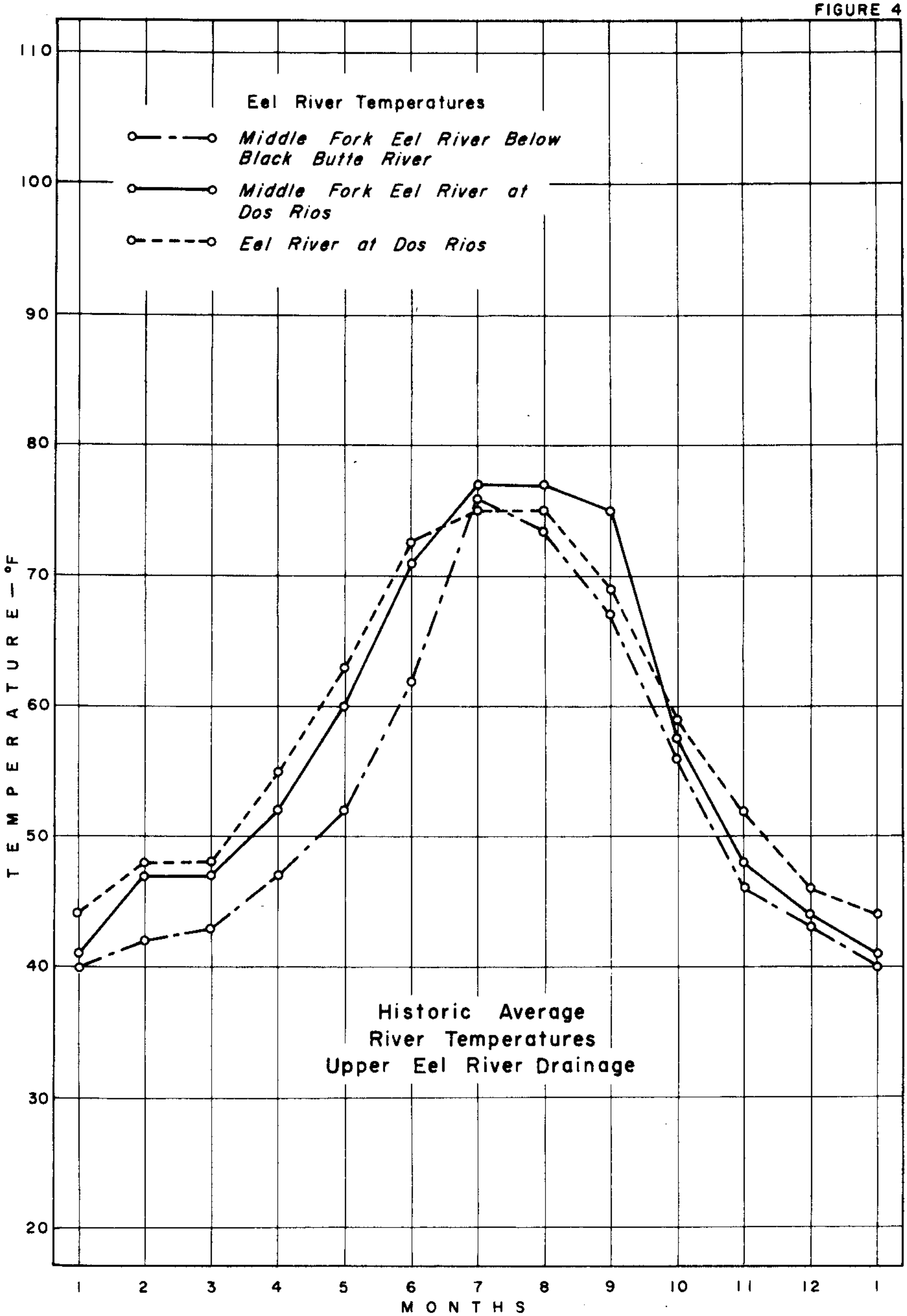
This water is of excellent mineral quality.

Temperature

Temperatures of present stream flows in the Middle Fork and Upper Main Eel Rivers are shown in Figure 4 . During the period November through February it can be seen that stream temperatures are below 50°F. ·During this same period approximately 80 percent of the runoff occurs. A considerable portion of the water placed in storage in Middle Fork Eel River Reservoirs would, therefore, be at a temperature less than 50°F. In addition, the depth of the reservoirs would be sufficient for the development of a thermocline which would provide a thermal blanket retarding the heating of the water below the thermocline level. Based on information available from similar reservoirs, it appears that the maximum depth of the thermocline in Upper Eel River reservoirs would be about 50 feet. This means that water from a depth of approximately 60 feet to the bottom of the reservoir will be generally 50°F or cooler. The quantity of water below a depth of 60 feet, the level at which water would be withdrawn from the reservoir, and the quantity of water drawn from a given level, will determine the availability of a given quantity of water, at a given temperature, at a given time.

With the incorporation of proper facilities for the selection of water at varying depths, and with pre-scheduled operation for temperature control, it is anticipated that there will not be any problem in providing water at temperatures within acceptable temperature ranges from any of the proposed reservoirs

FIGURE 4



Eel River Temperatures
Middle Fork Eel River Below Black Butte River
Middle Fork Eel River at Dos Rios
Eel River at Dos Rios
Historic Average River Temperatures Upper Eel River Drainage
TEMPERATURE — °F
110
100
90
80
70
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
1
MONTHS

on the Middle Fork Eel River. Temperature control over the same temperature range at sections on the upper ends of a reservoir may not be possible due to insufficient water depth and water volume.

Turbidity

The Middle Fork Eel River near Dos Rios stays turbid longer and contains higher levels of turbidity than does the Main Eel River at Dos Rios. Data indicate that of the major tributaries to the Middle Fork Eel River, Black Butte River is most turbid for the longest period of time.

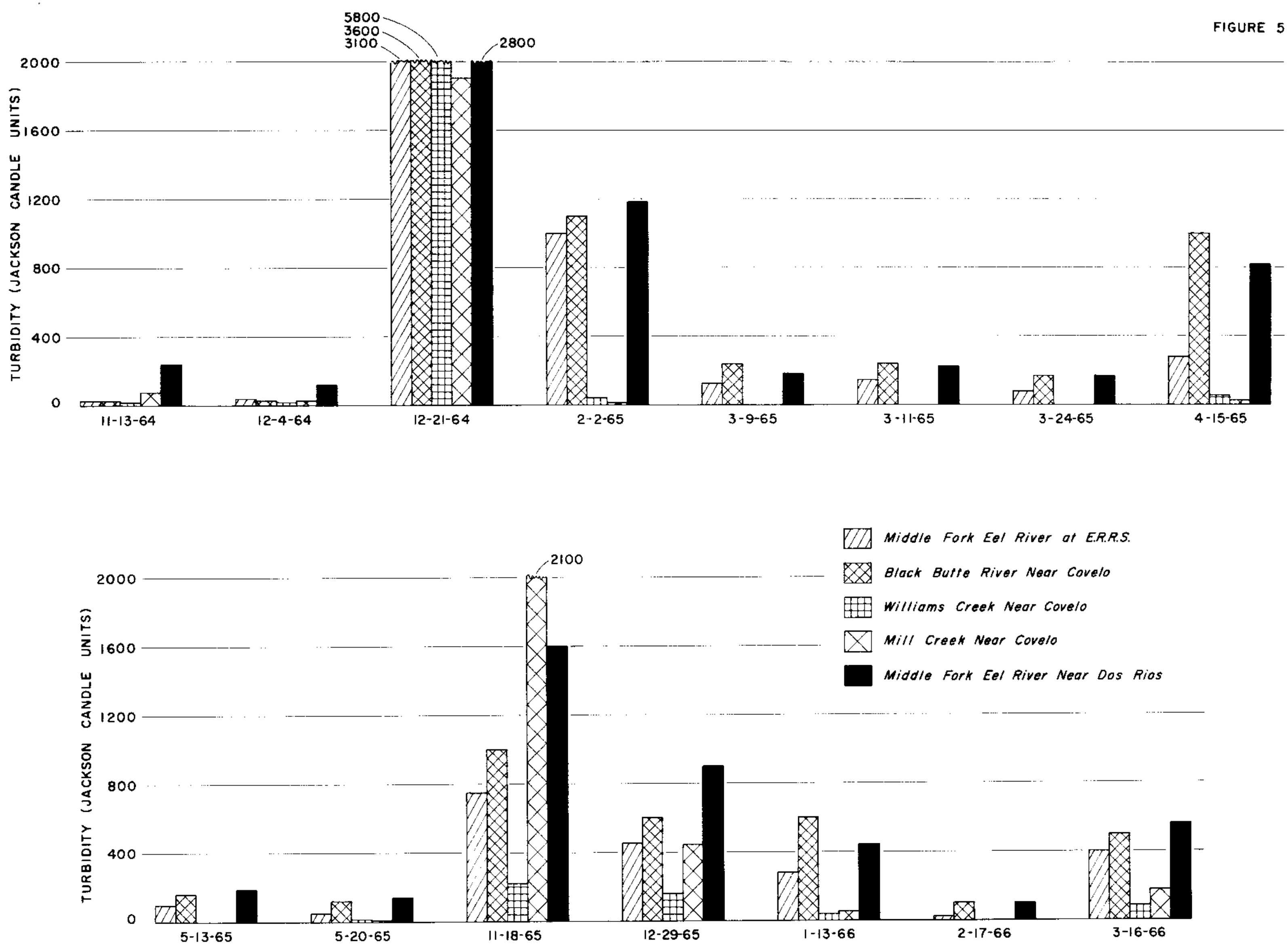
Figure 5 shows turbidity levels found in Middle Fork Eel River drainage for the period from November 1964 to March 1966. The drainage is nearly free of turbidity from July through October. Turbidity begins with the first fall storm.

Water from the primary turbidity sources - Mill Creek, Williams Creek, Middle Fork Eel River, and Black Butte River - would be impounded for a considerable period of time before it reaches the Dos Rios-Grindstone tunnel. A significant portion of the particulate material causing turbidity would, therefore, settle out of the water before reaching the tunnel entrance.

Elk Creek, another major source of turbidity, would enter Dos Rios Reservoir approximately two miles downstream from the Dos Rios-Grindstone tunnel. Suspended material entering Dos Rios Reservoir via Elk Creek will not affect the quality of the export water.

Two small streams would enter Dos Rios Reservoir near the tunnel entrance. These are Hayshed Creek, at the tunnel

FIGURE 5



TURBIDITY LEVELS IN MIDDLE FORK EEL DRAINAGE entrance, and Thatcher Creek approximately 3/4 mile below the tunnel entrance. Turbidity in these streams will be short lived following a storm; however, Hayshed Creek will have a significant effect on the peak levels of turbidity in the export water. In addition, sediment deposited near the tunnel entrance could cause a problem if the build-up is sufficient to obstruct the passage of water. Additional information is needed on the sediment load carried by Hayshed Creek and the pattern of sediment build-up expected at the entrance to the Dos Rios-Grindstone tunnel.

Turbidity in the export water may reach levels of from 500 to 1000 JCU during, and for short periods of time following, a storm. The high turbidity levels will be primarily due to run-off from Hayshed Creek. Since the quantity of water from Hayshed Creek is not expected to be great, the levels of turbidity at the tunnel will decline fairly rapidly due to settling of the particulate matter and displacement of the Hayshed Creek water. Once the turbidity from Hayshed Creek has been dissipated, the turbidity levels in the reservoir would be primarily due to up-stream drainage. A significant removal of turbidity would occur upstream from the tunnel. It appears, therefore, that turbidity in water exported from Dos Rios Reservoir will be in the following order of magnitude following a single storm.

Length of Time Following a Storm	Turbidity Level Resulting from an Average Storm
Days	JCU
0	500
10	200
20	80
30	50
40	25

Dissolved Oxygen

The dissolved oxygen content in Middle Fork Eel River drainage is at or near saturation throughout the year.

Following impoundment of the water, a thermocline will exist in the reservoirs from approximately the first of April to the end of October. Organic decomposition, especially during the first years of inundation, will probably deplete the dissolved oxygen content of the water below the thermocline. The dissolved oxygen level near the bottom of the reservoirs may reach zero, and hydrogen sulfide may be produced. Water discharging from tunnels taking water from near the bottom of the reservoir may have a hydrogen sulfide in it giving a distinct "rotten egg" odor.

Nutrients

The Middle Fork Eel River, near Dos Rios, has been tested for total phosphates and nitrates monthly since January, 1965. Prior to January, 1965, semi-annual tests were made for total phosphates and nitrates beginning in April, 1958.

Total phosphate levels have ranged during this period from 0.00 to 0.68 ppm with a median of 0.05 ppm. Nitrates have ranged from 0.0 to 2.10 ppm with a median of 0.3 ppm. These levels of nitrogen and phosphorous in water are sufficient to sustain plankton growths.

Nutrient data has also been obtained from Middle Fork Eel River above Black Butte River and the major tributaries to

Middle Fork Eel River. The following is a summary of these data obtained by monthly sampling since January, 1965.

Station	Total Phosphate		Nitrates	
	Range	Median	Range	Median
Middle Fork Eel River at Eel River Ranger St.	0.0-0.65	0.05	0.0-1.90	0.9
Black Butte River	0.02-0.61	0.10	0.0-2.50	1.3
Williams Creek	0.0-0.97	0.06	0.0-2.0	1.0
Mill Creek	0.05-0.86	0.10	0.6-2.60	1.2

Based on these data no one stream is an outstanding contributor of nutrients. All of the streams, however, contain nutrients in sufficient amounts to sustain aquatic growth.

In view of the above, plankton growth may be expected in reservoirs on the Middle Fork Eel River, especially in the shallow portions near the point of stream inflow. The growth, however, would not be as great as that in Clear Lake. Plankton growths are not expected to cause problems that will interfere with the recreational use of the reservoirs or other beneficial uses.

West Side Sacramento Valley

The proposed Glenn Reservoir Complex, comprised of Rancheria Reservoir, Newville Reservoir, and Paskenta Reservoir is being studied.

Rancheria and Newville Reservoirs would receive drainage from Stony Creek, Grindstone Creek and possibly diverted water from Middle Fork Eel River. Paskenta Reservoir would impound water from Thomes Creek drainage; excess flows would be spilled to Newville Reservoir.

The quality of Stony, Grindstone and Thomes Creeks are discussed in the following paragraphs.

Mineral Quality

Three surface water monitoring stations are located on Stony Creek: Station 13f near Fruto, Station 13c approximately 1/2 mile below Black Butte damsite, and Station 13a near the point of confluence of Stony Creek and the Sacramento River. The following tabulation shows ranges and medians of selected mineral characteristics found at these stations.

Station	Specific Cond. Range	Specific Cond. Median	Hardness Range	Hardness Median	Boron Range	Boron Median	% Sodium Range	% Sodium Median
13f	140-689	296	58-244	125	0.0-0.4	0.1	12-26	19
13c	194-634	306	84-234	130	0.2-0.3	0.2	13-28	28
13a	157-523	324	65-194	138	0.0-0.8	0.1	14-28	19

This water is a calcium-magnesium bicarbonate type of excellent mineral quality even though it is moderately hard and is more mineralized than Middle Fork Eel River water.

Two surface water monitoring stations are located on Thomes Creek: Station 13d at Paskenta and Station 95b just upstream from the mouth of Thomes Creek. Samples have been collected monthly for analysis since 1958 at Station 13d and since 1959 at Station 95b. The following tabulation shows ranges and medians of selected mineral characteristics found at these stations.

Station	Specific Cond. Range	Specific Cond. Median	Hardness Range	Hardness Median	Boron Range	Boron Median	% Sodium Range	% Sodium Median
13d	98-469	222	44-198	98	0.0-0.3	0.1	8-22	13
95b	120-323	222	54-146	108	0.0-0.2	0.0	7-15	10

The data indicates very little change in the mineral quality between Station 13d and Station 95b. Thomes Creek is of excellent mineral quality, satisfactory for nearly all beneficial uses.

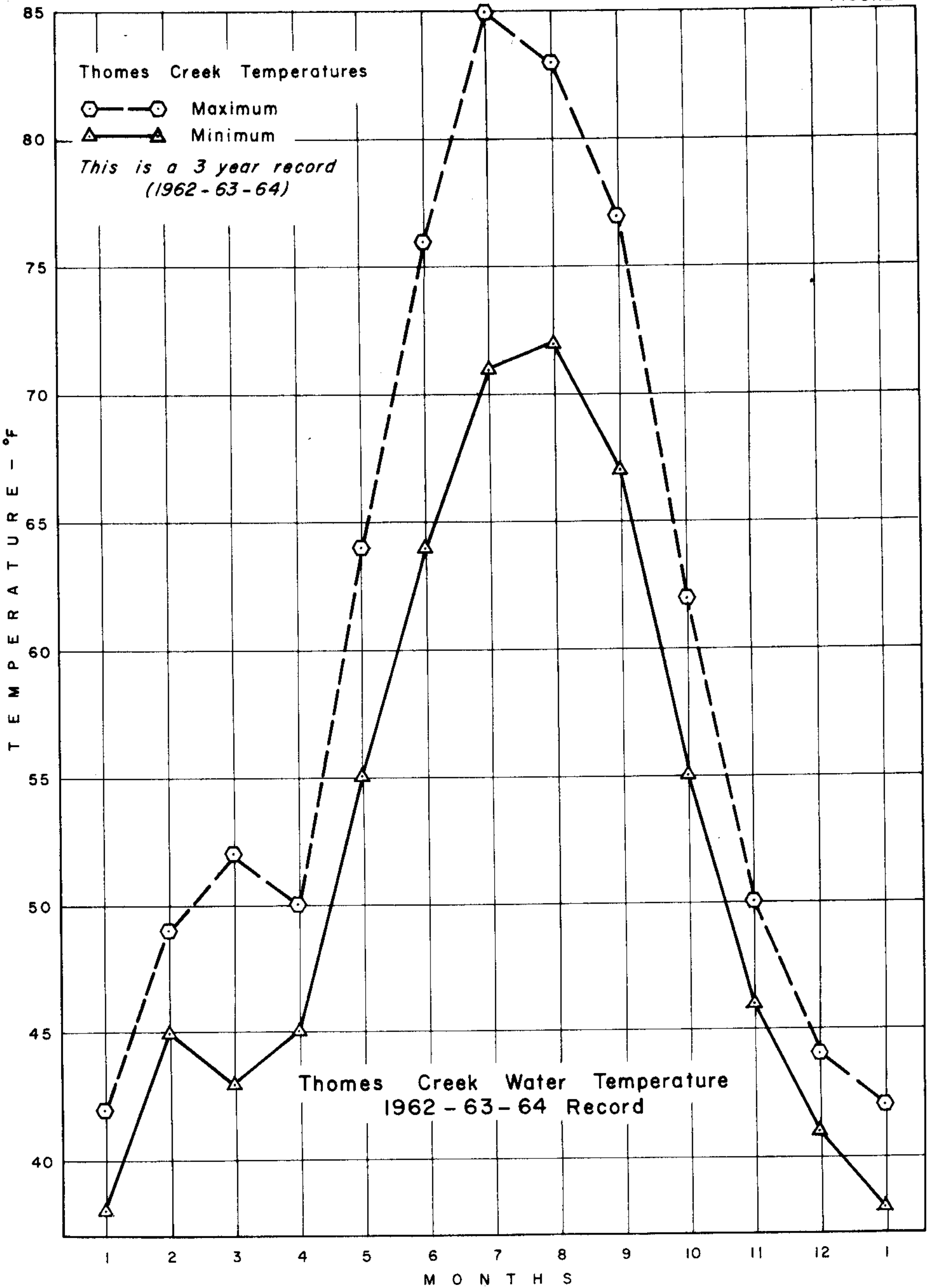
Mineral data from Grindstone Creek is limited. Available data, however, indicates that Grindstone Creek is of substantially the same mineral quality as Thomes Creek.

Temperature

Stony Creek is impounded by three reservoirs: East Park, Stony Gorge, and Black Butte. The operation of these reservoirs has an effect on the temperature of Stony Creek. Temperature data is available at several points on Stony Creek and temperature profiles have been taken from the three reservoirs. With information available at this time, however, it is difficult to separate the natural temperature influences from the man modified temperature influences. In view of this, specific data will not be presented on temperature in Stony Creek due to the fact that it is uncertain that it is representative of any average or normal conditions.

Figure 6 shows average maximum and minimum temperatures in Thomes Creek at Paskenta for a three year period. These

FIGURE 6



Thomes Creek Temperatures
Maximum
Minimum
This is a 3 year record (1962-63-64)
Thomes Creek Water Temperature 1962-63-64 Record
TEMPERATURE - °F
85
80
75
70
65
60
55
50
45
40
1
2
3
4
5
6
7
8
9
10
11
12
1
MONTHS

data show that during the periods of greatest runoff (November through March) the water temperature is below 50° F, the same as for the Middle Fork Eel River.

Turbidity

Figure 7 shows turbidity levels found in Thomes Creek near Paskenta, Stony Creek near Fruto and Stony Creek below Black Butte Dam from January 1965 to November 1965. During this period turbidity levels never dropped below 20 units in Stony Creek. The following tabulation gives the range of turbidity levels found at each station and the percentage of time that the levels were above 50 JCU.

Station	Turbidity Range JCU	% of time above 50 JCU
Stony Creek near Fruto	2000 - 20	73
Stony Creek below Black Butte	520 - 20	65
Thomes Creek at Paskenta	2800 - 0.	45

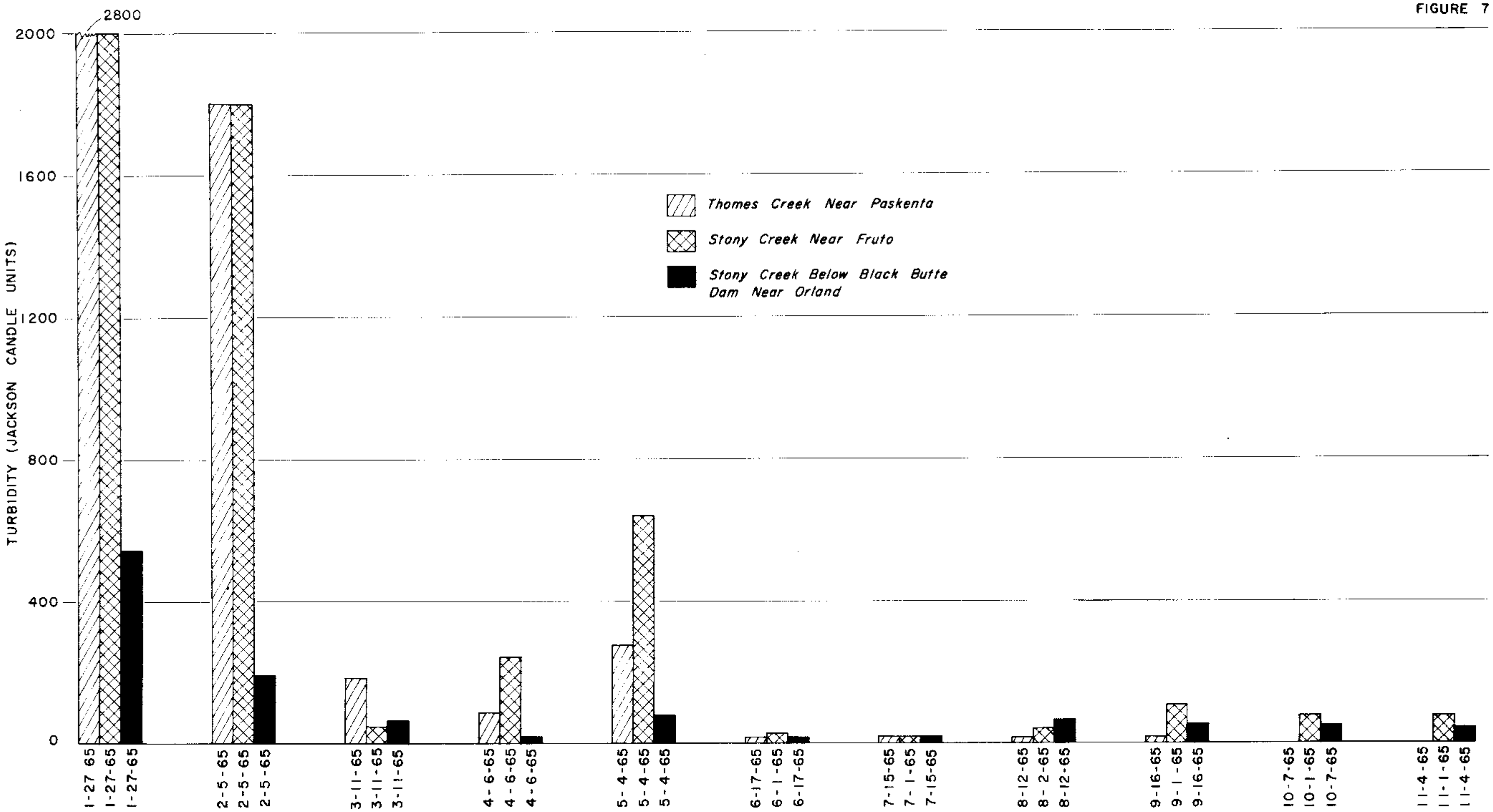
The Department of Fish and Game has indicated that fisherman generally do not fish in water that exceed 50 turbidity units.

Dissolved Oxygen

The dissolved oxygen levels in Stony and Thomes Creeks are at or near saturation throughout the year.

Nutrients

Nutrient data was obtained on a monthly basis from Stony Creek below Black Butte Reservoir, and Thomes Creek near Paskenta



TURBIDITY LEVELS IN THOMES CREEK AND STONY CREEK since January, 1965. The following is a summary of these data:

Station	Total Phosphate Range	Median	Nitrates Range	Median
Stony Creek	0.05-0.20	0.07	1.10-2.80	1.8
Thomes Creek	0.00-0.15	0.05	0.00-3.40	1.3

These values are well above the minimum levels of these constituents necessary for plankton growth.

Glenn Reservoir Complex

The quality of the water to be exported from the Middle Fork Eel River, and the quality of the water in Thomes, Grindstone, and Stony Creeks have been discussed in the previous paragraphs. The following discussion is devoted to the quality of water that may result in the impoundments of the Glenn Reservoir Complex.

Rancheria and Newville Reservoirs

Drainage from Stony and Grindstone Creeks, as well as export water from the Middle Fork Eel River, may be impounded in Rancheria and Newville Reservoirs. The quality of the water following impoundment is indicated below.

Mineral Quality

Utilizing operation schedule 4-G, the mineral quality of the water that would be discharged from Rancheria and Newville Reservoirs was obtained by weighting the mineral quality according to flow. The results indicate that the water discharging from these reservoirs would have the following concentrations of significant mineral characteristics:

Characteristic	Average Concentration
Specific Conductance	200 micromhos
Hardness	89 ppm
Boron	.07 ppm
Percent Sodium	13 percent

This water is of excellent mineral quality.

Temperature

With multiple level outlets on Rancheria and Newville Reservoirs water temperature control can be obtained. A range of water temperatures would be available within the reservoir for all known beneficial uses. If the Glenn route is selected, firm operation schedules would be established and detailed studies would be made to determine optimum temperature control procedures.

Nutrients

Adequate levels of nutrients for aquatic biota will be available in the impounded water. Some nuisance growth may occur at times in undisturbed, shallow portions of the reservoirs. It is not anticipated, however, that a problem similar to Clear Lake will exist in the reservoirs or that recreation or other beneficial uses of the water will be significantly restricted or the water made less desirable due to plankton growth.

Turbidity

The primary contributor of turbid water to Rancheria Reservoir would be Grindstone Creek. Water imported from the Middle Fork Eel River will be generally less turbid than the normal flow from Grindstone drainage during the winter and spring.

Portions of Rancheria and Paskenta Reservoirs will be turbid during a part of each year. The highest levels of turbidity will occur in an area near the surface water inlets to the reservoirs.

By June turbidity in the inflowing water will have reached low values, and the turbidity which entered the reservoirs during the winter will have decreased to a considerable extent due to settling. It is, therefore, not anticipated that recreation will be significantly affected due to turbid water.

It is possible that turbidity currents will exist in the reservoirs even after the surface waters have become relatively free of turbidity. Again, multiple level outlets on the reservoirs will aid in minimizing turbidity in the reservoir releases.

Dissolved Oxygen

Dissolved oxygen levels will follow the same general pattern described for the Middle Fork Eel River Reservoirs.

Paskenta Reservoir

Paskenta Reservoir will impound Thomes Creek water and spill excess flows into Newville Reservoir. The following is a description of the water quality expected in water released from Paskenta Reservoir.

Mineral Quality

The mineral quality of the water following its impoundment in Paskenta Reservoir was determined by weighting the mineral quality of Thomes Creek by its flow. The following tabulation shows weighted averages of significant mineral characteristics:

Characteristic	Weighted Average Concentration
Special Conductance	157 micromhos
Hardness	72 ppm
Boron	.04 ppm
Percent Sodium	11 percent

This water is of excellent mineral quality, satisfactory for nearly all beneficial uses.

Temperature

Fishery enhancement is one of the possible purposes of Paskenta Reservoir. If enhancement is to be obtained in Thomes Creek below Paskenta Reservoir, the temperature of the water released from the reservoir must be within acceptable ranges.

Paskenta Reservoir, with a storage of 105,000 acre-feet, would have a maximum depth of 200 feet and a minimum depth of 135 feet. Water temperatures within acceptable limits for anadromous fish would be contained within this depth range. Factors which determine the availability of water at a satisfactory temperature were discussed in a previous section.

Multiple level outlets would be required, and the operation schedule for the reservoir should be designed around water quality for fishery enhancement if this benefit is of sufficient weight to control the operation plan. It does not appear that the reservoir will be large enough to allow a range of operational plans which will satisfy all benefits at all times.

Turbidity

Data indicate that Thomes Creek contains levels of turbidity above 20 JCU from November through May. From the middle of June until the first fall storm, Thomes Creek is relatively free of turbidity.

Following impoundment of the water, the turbidity will persist at levels above 25 JCU for approximately 60 days. This means that by the end of July the water released from Paskenta Reservoir may be expected to be fairly clear. Multiple level outlets will aid in controlling the level of turbidity in the water released from the reservoir.

Nutrients

Sufficient nutrients will be available in Thomes Creek water for plankton growth. The growth pattern in this body of water should be similar to that expected in Rancheria-Newville. The depth of these reservoirs will be sufficient to retard excess growth due to the lack of redistribution of nutrients from the bottom of the reservoirs to the euphotic zone. Some nuisance growths may occur in shallow inlet portions of the reservoirs; however, conditions which would interfere with beneficial uses of the impoundment are not expected.

Dissolved Oxygen

A thermocline will exist in Paskenta Reservoir from approximately the end of April until the end of October. The thermocline is expected to reach a maximum depth of about 50 feet.

Following the establishment of a thermocline, the dissolved oxygen level below the thermocline elevation will start to decrease. By the end of summer the level of dissolved oxygen may reach zero near the bottom of the reservoir, and hydrogen sulfide may be produced.

The water above the thermocline will contain dissolved oxygen at or near saturation throughout the year. By approximately the middle of November the waters in the reservoir will turnover, destroying the thermocline and redistributing dissolved oxygen throughout the reservoir profile.

Multiple level outlets will aid in preventing problems due to low dissolved oxygen levels near the bottom of Paskenta Reservoir and other reservoirs of the Glenn Complex.

Glenn Salt Routing

A trial salt routing study was made from the Middle Fork Eel River to the Sacramento River. Plate Number 2 presents a summary of mineral quality changes for the entire routing, beginning at Dos Rios Reservoir. The export water will be Class I for irrigation throughout the system and will be of excellent mineral quality, suitable for nearly all beneficial uses.

The effect on the mineral quality of the Sacramento River of utilizing the Glenn Route (Dos Rios-Grindstone tunnel) is shown in the following tabulation:

Characteristic	Present Median Level in the Sacramento River	Median Level in the Sacramento River Following the Addition of Export Water
Specific Conductance	124 micromhos	134 micromhos
Hardness	50 ppm	55 ppm
Boron	0.03 ppm	0.04 ppm
Percent Sodium	22 percent	21 percent

Gnats

The Clear Lake variety of gnats (Chaoborus Astictapus) exist at the present time at Black Butte Reservoir. Entomologists of Tehama and Glenn Counties are currently looking into the problem. No control program, however, has been established at Black Butte as yet.

Future reservoirs of the Glenn Complex will undoubtedly provide a habitat for gnats. Although it is doubtful that the gnat problem will become as acute as it has been at Clear Lake, a control program may have to be initiated at the reservoirs in order to realize their full recreation potential.

ADDITIONAL SOURCES OF DATA AND INFORMATION

Additional data and information related to water quality in the North Coastal Area of California are available in the following publications:

1. California Department of Water Resources. "Clear Lake Water Quality Investigation". Bulletin No. 143-2. March 1966

2. - - Northern District. "Quality of Ground and Surface Waters in the North Coastal Area". Office Report. November 1964.

3. - - Northern District. "Turbidity and its Measurement in North Coastal California". Office Report. March 1966.

APPENDIX A

WATER QUALITY CRITERIA

WATER QUALITY CRITERIA

In all activities dealing with observation and measurement of physical data, there must be a yardstick or standard by which the observer, planner, or user can judge or classify the information gathered. With regard to water quality, the problem becomes one of determining whether or not water is suitable for the anticipated use or uses.

Criteria presented in the following sections can be utilized in evaluating mineral quality of water relative to the broad categories of beneficial uses indicated. It should be noted that these criteria are merely guides to the appraisal of water quality. Except for those constituents which are considered toxic to human beings, these criteria are suggested, rather than mandatory, limiting values. Water which exceeds one or more of these limiting values need not be eliminated from consideration as a source of supply, but other sources of better quality water should be investigated.

Criteria for Drinking Water

Criteria for appraising the suitability of drinking water and water supply systems used by carriers and others subject to Federal quarantine regulations have been promulgated by the U. S. Public Health Service. The limiting concentrations of chemical substances in drinking water have been abstracted from these criteria and are shown in the following tabulation. Other organic or mineral substances may be limited if their presence renders the water hazardous for use.

Interim standards for certain mineral constituents have been adopted by the California State Board of Public Health. Based on these standards, temporary permits may be issued for drinking water supplies failing to meet the United States Public Health Service Drinking Water Standards, provided the mineral constituents in the following table are not exceeded.

UPPER LIMITS OF TOTAL SOLIDS AND SELECTED MINERALS IN DRINKING WATER AS DELIVERED TO THE CONSUMER

	Permit	Temporary Permit
Total solids	500 (1000)*	1500 ppm
Sulfates (SO_4)	250 (500) *	600 ppm
Chlorides (Cl)	250 (500) *	600 ppm
Magnesium (Mg)	125 (125)	150 ppm

* Numbers in parentheses are maximum permissible, to be used only where no other more suitable water is available in sufficient quantity for use in the system.

The California State Board of Public Health also has defined the maximum safe amounts of fluoride ion in drinking water in relation to mean annual temperature. These relationships are tabulated below.

RELATIONSHIP OF TEMPERATURE TO FLUORIDE CONCENTRATION IN DRINKING WATER

Mean annual Temperature	Mean monthly fluoride ion concentration
50°F	1.5 ppm
60°F	1.0 ppm
70°F-above	0.7 ppm

Criteria for Irrigation Water

Criteria for mineral quality of irrigation water have been developed by the United States Regional Salinity Laboratory in cooperation with the University of California. Because of diverse climatological conditions and the variation in crops and soils in California, only general limits of quality for irrigation waters can be suggested. The department uses three broad classifications of irrigation waters as listed below.

Class I - Regarded as safe and suitable for most plants under most conditions of soil and climate.

Class 2 - Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher ranges of this class.

Class 3 - Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

Limiting concentrations of chemical constituents in irrigation water as classified above are shown in the following tabulation:

QUALITATIVE CLASSIFICATION OF IRRIGATION WATER

Chemical Properties	Class 1 Excellent to good	Class 2 Good to injurious	Class 3 Injurious to unsatisfactory
Total dissolved solids, in ppm	Less than 700	700 - 2000	More than 2000
Conductance, in Micromhos at 25°C	Less than 1000	1000 - 3000	More than 3000
Chlorides, in ppm	Less than 175	175 - 350	More than 350
Sodium, in percent of base constituents	Less than 60	60 - 75	More than 75
Boron, in ppm	Less than 0.5	0.5 - 2.0	More than 2.0

These criteria have limitations in actual practice. In many instances, water of a given quality may be wholly unsuitable for irrigation under certain conditions of use, and yet be completely satisfactory under other circumstances. Soil permeability, drainage, temperature, humidity, rainfall, and other conditions can alter the response of a crop to a particular quality of water.

Criteria for Industrial Uses

Water quality criteria for industrial water are as varied and diversified as industry itself. Food processing, beverage production, pulp and paper manufacturing, and textile industries have exacting requirements, while cooling or metallurgical operations permit the use of poor quality water. In general, where a water supply meets drinking water standards, it is satisfactory for many industrial uses; either directly or following a limited amount of polishing treatment by the industry.

Hardness

Even though hardness in water is not included in the foregoing criteria, it is important in domestic and industrial uses. Excessive hardness in water used for domestic purposes causes increased consumption of soap and formation of scale in pipe and fixtures. Values for degrees of hardness which are used in this report are shown in the following tabulation:

HARDNESS CLASSIFICATION

Range of hardness, expressed as $CaCO_3$ in ppm	Relative Classification
0 - 100	Soft
101 - 200	Moderately hard
Greater than 200	Hard

CLEAR LAKE ROUTE MINERAL PREDICTION

PRESENT CONDITIONS

	MIDDLE FORK EEL RIVER	UPPER EEL RIVER	CLEAR LAKE	N/F CACHE CREEK	PUTAH CREEK	SACRAMENTO RIVER at mouth of Cache Cr.	SACRAMENTO RIVER at mouth of Putah Cr.
Runoff	1,210 AF/Yr.	713 AF/Yr.	268 AF/Yr.	135 AF/Yr.	343 AF/Yr.	7188 AF/Yr.	16,340 AF/Yr.
E.C.	137	132	262	227	320	152	162
Boron (ppm)	0.06	0.17	0.90	0.80	0.20	0.04	0.04

PROJECT CONDITIONS

ENGLISH RIDGE ONLY VIA PUTAH CREEK

	ENGLISH RIDGE RES.	CLEAR LAKE	LAKE BERRYESSA	SACRAMENTO RIVER
	Releases 212 AF/Yr.	Releases 480 AF/Yr.	Releases 555 AF/Yr.	Runoff 16,340 AF/Yr.
E.C.	132	205	276	166
Boron (ppm)	0.17	0.58	0.35	0.07

212 AF/Yr. — 212 AF/Yr. — 555 AF/Yr.

DOS RIOS PLUS ENGLISH RIDGE VIA PUTAH CREEK

	DOS RIOS RES.	ENGLISH RIDGE RES.	CLEAR LAKE	LAKE BERRYESSA	SACRAMENTO RIVER
	Releases 667 AF/Yr.	Releases 1,046 AF/Yr.	Releases 1,314 AF/Yr.	Releases 1,389 AF/Yr.	Runoff 17,804 AF/Yr.
E.C.	137	132	160	200	165
Boron (ppm)	0.06	0.17	0.30	0.30	0.06

667 AF/Yr. — 1,046 AF/Yr. — 1,046 AF/Yr. — 1,389 AF/Yr.

DOS RIOS PLUS ENGLISH RIDGE VIA CACHE CREEK

	DOS RIOS RES.	ENGLISH RIDGE RES.	CLEAR LAKE	WILSON VALLEY RES.	SACRAMENTO RIVER
	Releases 667 AF/Yr.	Releases 1,046 AF/Yr.	Releases 1,314 AF/Yr.	Releases 1,449 AF/Yr.	Runoff 8,637 AF/Yr.
E.C.	137	132	160	166	154
Boron (ppm)	0.06	0.17	0.30	0.35	0.09

667 AF/Yr. — 1,046 AF/Yr. — 1,314 AF/Yr. — 1,449 AF/Yr.

Runoff in Thousands of Acre-Feet Per Year

GLENN ROUTE MINERAL PREDICTION

PRESENT CONDITIONS

	MIDDLE FORK EEL RIVER	THOMES CREEK	STONY CREEK	SACRAMENTO RIVER
Runoff	1,210 AF/Yr.	191 AF/Yr.	397 AF/Yr.	8,246 AF/Yr.
E.C.	137	157	331	123
Hardness	64	72	141	49
Boron (ppm)	0.06	0.04	0.10	0.03
Percent Sodium	10	11	19	22

PROJECT CONDITIONS

MIDDLE FORK EEL RIVER VIA DOS RIOS -GRINDSTONE TUNNEL

	DOS RIOS RES.	RANCHERIA - NEWVILLE	SACRAMENTO RIVER
	Releases 826 AF/Yr.	Releases 1,223 AF/Yr.	Runoff 9,660 AF/Yr.
E.C.	137	200	134
Hardness	64	89	55
Boron (ppm)	0.06	0.07	0.04
Percent Sodium	10	13	21

DOS RIOS RES. → 826 AF/Yr. → RANCHERIA - NEWVILLE → 1,223 AF/Yr. → SACRAMENTO RIVER

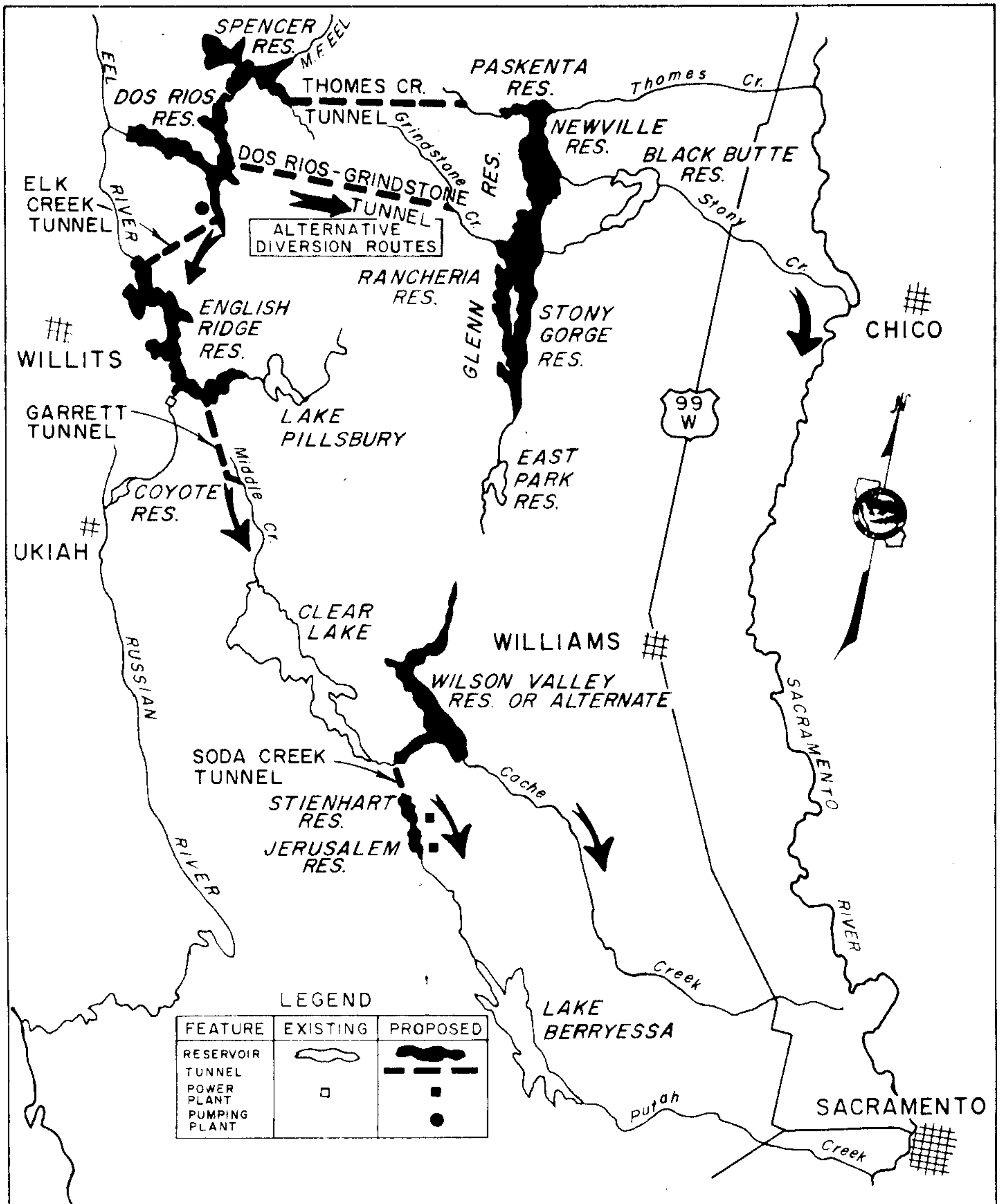
MIDDLE FORK EEL RIVER VIA SPENCER - THOMES CREEK TUNNEL

	SPENCER RES.	PASKENTA - NEWVILLE	BLACK BUTTE RES.	SACRAMENTO RIVER
	Releases 580 AF/Yr.	Releases 684 AF/Yr.	Releases 1,081 AF/Yr.	Runoff 9,374 AF/Yr.
E.C.	137	142	211	133
Hardness	64	66	94	55
Boron (ppm)	0.06	0.07	0.08	0.04
Percent Sodium	10	10	13	21

SPENCER RES. → 580 AF/Yr. → PASKENTA - NEWVILLE → 684 AF/Yr. → BLACK BUTTE RES. → 1,081 AF/Yr. → SACRAMENTO RIVER

Runoff in Thousands of Acre-Feet Per Year

PLATE 3



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

UPPER EEL RIVER DEVELOPMENT